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(NASA-CR-163804) POINT FOCUSING THERMAL AND ELECTRIC APPLICATIONS PROJECT. VOLUME 2: WORKSHOP PROCEEDINGS (BDM Corp., McLean, Va.) 241 p HC A11/MF A01 CSCL 10A

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POINT FOCUSING THERMAL AND ELECTRIC APPLICATIONS PROJECT

WORKSHOP FOR POTENTIAL MILITARY AND CIVIL USERS OF SMALL SOLAR THERMAL ELECTRIC POWER TECHNOLOGIES

HELD AT
The BDM Corporation
McLean, Virginia
September 11-14, 1979

VOLUME II

WORKSHOP PROCEEDINGS

Prepared for the
U.S. Department of Energy
Through an Agreement with
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL Contract 955354

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Edited by
Karen E. Landis
The BDM Corporation

ORIGINAL CONTAIN
COLOR ILLUSTRATIONS

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U.S. Department of Energy
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The workshop described in this document was carried out by The BDM Corporation for the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the Department of Energy by agreement with the National Aeronautics and Space Administration.

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Proceedings reports of working groups represent the concensus of each group. They are not necessarily the opinions of any single individual. They do not represent the official policy of any agency represented.

Question and answer sessions are presented in summary form following each presentation. Only the person questioned has been identified.

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FOREWORD

The Workshop for Potential Military and Civil Users of Small Solar Thermal Electric Power Technologies was held at The BDM Corporation in McLean, Virginia on September 11-14, 1979. This meeting was sponsored by the U.S. Department of Energy (DOE). The workshop was part of the Jet Propulsion Laboratory's (JPL) Point Focusing Thermal and Electric Applications Project.

The workshop, which was chaired by Mr. J. Scott Hauger, was made up of four working groups: Portable Applications, Isolated Applications, Facilities Applications, and Implementation. Presentations included, keynote addresses made by representatives of the U.S. Department of Defense and the U.S. Department of Energy, individual presentations, question and answer sessions, and working group reports. The presentations are included here in their entirety. Discussions are included in summary form.

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ACKNOWLEDGEMENTS

The contributions of those who attended the workshop are gratefully acknowledged. The success of the workshop was due to the information exchange generated by each presenter and attendee.

This document was complied and edited by Karen E. Landis, Workshop Coordinator/Program Manager under the direction of J. Scott Hauger, Associate Manager for Military Energy Programs.

Dean Wingfield provided helpful technical support. Katrina Robey was responsible for preparing the manuscript.

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WORKSHOP FOR POTENTIAL
MILITARY AND CIVIL USERS OF
SMALL SOLAR THERMAL ELECTRIC
POWER TECHNOLOGIES

VOLUME II - WORKSHOP PROCEEDINGS
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POINT FOCUSING THERMAL AND
ELECTRIC APPLICATIONS PROJECT

JPL SOLAR THERMAL ELECTRIC POWER USERS WORKSHOP

The BDM Corporation
The BDM Corporation Conference Center
(Westbranch Facility)
Chairman - J. Scott Hauger

AGENDA

Tuesday, September 11, 1979

INTRODUCTION

6:00 pm	Welcome and Introduction	JPL	T. Kuehn
6:15 pm	Point Focusing Distributed Receiver Solar Thermal Power	JPL	V. Truscello
7:30 pm	Introduction of Working Groups	BDM	J. S. Hauger
8:00 pm	Reception		

AGENDA

Wednesday, September 12, 1979

KEYNOTE SPEAKERS

8:15 am	Welcome	BDM	Earle C. Williams, President, The BDM Corporation
8:30 am	DOD Keynote Speaker	DOD	George Marienthal, Deputy Asst. Secretary of Defense for Energy, Environment & Safety
9:00 am	Questions/Discussion Period		
9:15 am	DOE Keynote Speaker	DOE	Martin Adams, Deputy Program Director for Solar, Geothermal, Electric & Storage Systems
9:45 am	Coffee Break and Questions		

APPLICATIONS OVERVIEW

10:00 am	Military Applications for Solar Thermal Electric Power Systems	BDM	J. S. Hauger
10:30 am	Solar Thermal Electric Power Systems Impact Analysis and Requirements	SAI	Y. Gupta
11:00 am	Questions/Discussion Period		
11:30 - 12:50 pm	Working Lunch/Group Meetings		

REQUIREMENTS FOR ISOLATED POWER SYSTEMS

1:00 pm	Communications Sites Applications and Requirements	D.C.A.	E. Phillip
1:30 pm	Island Applications and Requirements for Solar Power Systems	State of Hawaii	E. Grabbe
2:00 pm	Developing Country Applications and Requirements	AID	Alan Poole
2:30 pm	Coffee Break and Questions		

AGENDA

Wednesday, September 12, 1979

A RELATED SOLAR THERMAL APPLICATION

3:00 pm	The Production of Mobility Fuels	LLL D. Gregg
3:30 pm	Questions/Discussion Period	
3:45 - 5:05 pm	Group Meetings	
5:15 pm	Summary and Adjournment	
7:00 pm	WORKSHOP DINNER - TYSONS CORNER HOLIDAY INN	

AGENDA

Thursday, September 13, 1979

8:15 am	Coffee		

REQUIREMENTS FOR PORTABLE POWER

8:30 am	Military Theater Applications and Requirements	USAF APL	Lt. R. Honneywell
9:00 am	Questions and Coffee Break		
9:30 am	Portable Power Applications and Requirements	U.S. Army TRADOC	T. Batty
10:00 am	Rental Equipment Applications and Requirements	Curtis Engine	V. Waugh
10:30 am	Questions/Discussion Period		
11:00 - 1:20 pm	Working Lunch/Group Meetings		

REVIEW OF CURRENT APPLICATIONS EXPERIMENTS

1:30 pm	Engineering Experiment I	JPL	T. Kicenjuk
2:00 pm	Engineering Experiment II	JPL USN	R. Levin L. Huang
2:30 pm	Coffee Break and Questions		

IMPLEMENTATION

2:45 pm	Informal Panel Discussion: Implementation of DOD Research and Development	USAF USN USN	CPT. D. Hall P. Ritzcoven M. Carr
3:45 pm	Standardization and Implementation	PM-MEP	Col. A. Rowe
4:15 pm	Questions/Discussion Period		
5:30 pm	Summary and Adjournment		

AGENDA

Friday, September 14, 1979

8:15 am	Coffee		
	IMPLEMENTATION		
8:30 am	Introductory Remarks		
8:45 am	Manufacturers' and Production Implementation	SEIA	J. Connolly
9:15 am	The Role for Congress	U.S. Congress	Senator Pete V. Domenici (R N.M.)
10:00 am	Coffee Break and Questions		
10:45 - 12:20 pm	Group Meetings/Working Lunch		
	GROUP REPORTS		
12:30 pm	Group I Report		
1:00 pm	Group II Report		
1:30 pm	Group III Report		
2:00 pm	Group IV Report		
2:30 pm	Summary and Closing Remarks		

INTRODUCTION

HEAT AND ELECTRICITY FROM THE SUN USING PARABOLIC DISH COLLECTOR SYSTEMS

Vincent C. Truscello and A. Nash Williams
Jet Propulsion Laboratory
Pasadena, California

This paper addresses point focus distributed receiver (PFDR) solar thermal technology for the production of electric power and of industrial process heat, and describes the thermal power systems project conducted by JPL under DOE sponsorship. Project emphasis is on the development of cost-effective systems which will accelerate the commercialization and industrialization of plants up to 10 MWe, using parabolic dish collectors. The characteristics of PFDR systems and the cost targets for major subsystems hardware are identified. Markets for this technology and their size are identified, and expected levelized bus bar energy costs as a function of yearly production level are presented. Finally, the present status of the technology development effort is discussed.

1. Introduction

The solar thermal power systems work at JPL is sponsored by the Department of Energy, Thermal Power Systems Branch, for the purpose of developing systems capable of competitive-priced thermal and electric energy for utility, industrial, and isolated applications. Program responsibility resides with DOE Headquarters and project management with JPL, with engine and power conversion support provided by NASA Lewis Research Center.

Three principal configurations for thermal power systems being developed by DOE are the central receiver (CR), the line focus distributed receiver (LFDR), and the point focus distributed receiver (PFDR). The JPL work is based on a PFDR system with paraboloidal dish and integral receiver. This technology is expected to be initially applied to relatively small power systems (up to a few megawatts) made up of identical modules (each a few tens of kilowatts in capacity). Each module is capable either of generating electricity, or of supplying heat for industrial purposes, depending on the type of receiver used. A representative dish configuration is shown in Figure 1.

For electric applications the module consists of three subsystems: the concentrator, the receiver, and the power conversion unit. An automatic control system enables each module to track the sun across the sky every day. The concentrator collects solar energy from a large area and focuses it to a very small area. The receiver, which is mounted at the focal point, captures the concentrated radiation, and converts the energy to heat in a working fluid, such as hot gas. The working fluid transports the energy to the heat engine of the power conversion unit, which is mechanically linked to the electric generator. In the simplest configuration of the system, the power conversion unit is located atop the receiver, at the focus. The optical portion of the concentrator is a parabolic reflector, although lens concentrators are also being considered. To produce thermal energy for industrial, commercial, or agricultural applications, the power conversion unit is replaced with an appropriate receiver having flexible lines to conduct the working fluid to a heat transfer network on the ground.

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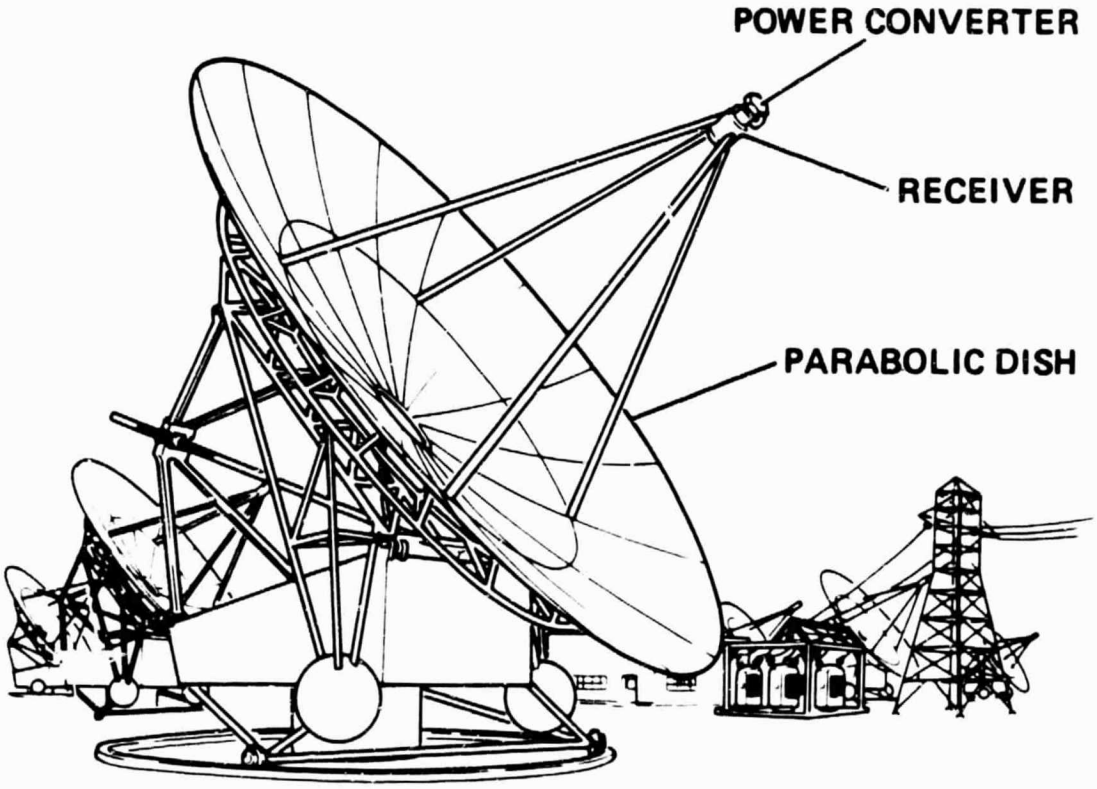

Figure 1. Dish Concentrator with Power Converter at the Focus

The principal advantages of the parabolic dish system and its characteristics are discussed below.

2. Point Focus Distributed Receiver (PFDR)

Advantages

The thermal power systems project at JPL began work under DOE sponsorship in June 1977. Prior studies by JPL under NASA funding had established PFDR systems as the solar thermal approach having the potential for producing low-cost energy. The principal advantages of dish solar concentrators are (1) the high temperatures attainable, (2) the inherent modularity of dish collectors, (3) the ease of collecting the power output of each dish in electrical form, and (4) the high percentage of the available solar insolation which is collected. The high temperatures available from dish systems results from their inherently high concentration ratio.

The attractiveness of the high temperature characteristic of dish systems arises from both the higher conversion efficiency achievable from heat engines as the temperature of the working fluid is increased and the wide range of temperatures achievable for thermal applications. The attractiveness of the inherent modularity of dishes with integral power converter at the focus lies in the strong potential for reduction in manufacturing costs as mass production experience evolves. For solar thermal dish systems to compete successfully with fossil fuels will require substantial progress in reducing manufacturing costs. Modularity facilitates this process, and in addition offers low risk during the development phases because it permits full-scale experiments with small hardware modules. Modularity also offers power plant growth on a flexible and incremental, building block, basis; performance is insensitive to plant power level. These features are summarized in Table I.

TABLE 1. WHY PFDR TECHNOLOGY

- TWO-AXIS COLLECTION
- HIGH CONCENTRATION HIGH TEMPERATURE
  HIGH CONVERSION EFFICIENCY
- ELECTRIC TRANSPORT
- WIDE TEMPERATURE RANGE HEAT PRODUCTION
- MODULAR MASS PRODUCTION

The ready adaptability of dishes to two-axis tracking insures maximum utilization of the direct beam radiation at near maximum efficiency from sun up to sun down. Two-axis tracking combined with the high geometric concentration ratio provides high temperatures at the focus, which in turn allows high efficiencies to be derived from Brayton or Stirling heat engine power converters. PFDR systems offer broad applicability, including both small and large utilities, power for remote sites, agriculture (especially pumping), and a wide range of industrial and commercial process heat applications.

Versatility as shown in Figure 2 is a key attribute of solar thermal systems, especially of dishes because of their high temperature potential. Versatility can be illustrated in terms of the end product produced: electricity, process heat, steam, chemicals and fuels.

With a power conversion unit consisting of a heat engine, alternator and receiver attached at the focus, electricity is produced. With only a receiver at the focus, steam or industrial process heat can be supplied. Also the dish units can be thermally coupled to supply high quality heat to a conventional power plant in a repowering mode. Combining engine and thermal transport allows these units to be used in cogeneration applications. Also, by adapting the receiver design to match the particular fuel or chemical to be produced, the dish system is adaptable to a wide range of chemical processes.

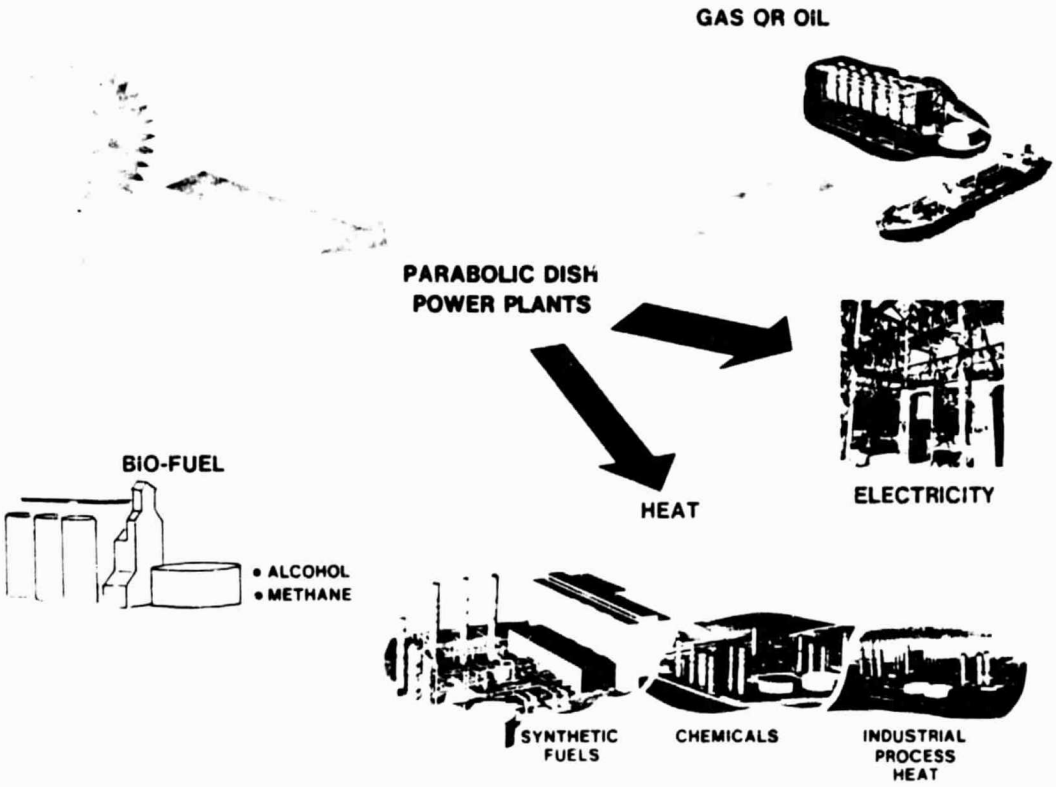

Figure 2. Versatility of Parabolic Dish Power Plants

Considering flexibility in terms of operational modes, dish systems can readily be designed to provide for hybrid operation in which conventional fuels provide heat on a transient or steady state basis to compensate for variations in insolation. Along with the hybrid operational capability, there is the potential for using numerous conventional fuels. A potentially attractive hybrid mode is the coupling of the solar plant to a biomass system to supply it with low Btu biogas produced by a digestive process. The most appropriate fuel would be selected for each application.

3. Market Size and Project Goals

The primary goals of the project are (1) to produce electricity or heat at a cost competitive with conventional alternatives, and (2) to develop the technical and economic readiness of cost-effective PFDR technology necessary to accelerate market penetration of small power systems. Market penetration requires a mature technology coupled with favorable preconditions within the commercial and industrial infrastructures which govern the effectiveness of supply and demand forces. To facilitate the establishment of preconditions increasingly more favorable to market penetration, the project will attempt to enter market areas of high-cost energy first and to enter large markets with corresponding lower energy costs later.

Figure 3 displays this overall market strategy. Economic value and energy cost in Figure 3 are represented in terms of life cycle levelized energy cost expressed in mills/kWh. Studies conducted by JPL indicate that there already exists a small near-term relatively high-cost energy market (Ref. 1). This market is known as the isolated load market, where the user is isolated from the grid. The local utility plant consists of little more than a few diesel generators and a small transmission and distribution network. This application is typical of small communities on U.S. islands in the Pacific and Caribbean, remote military installations, and villages in developing countries. For the isolated load market, the estimates of levelized bus bar energy costs range from 150 to 200 mills/kWh in the 1990-2000 time frame.

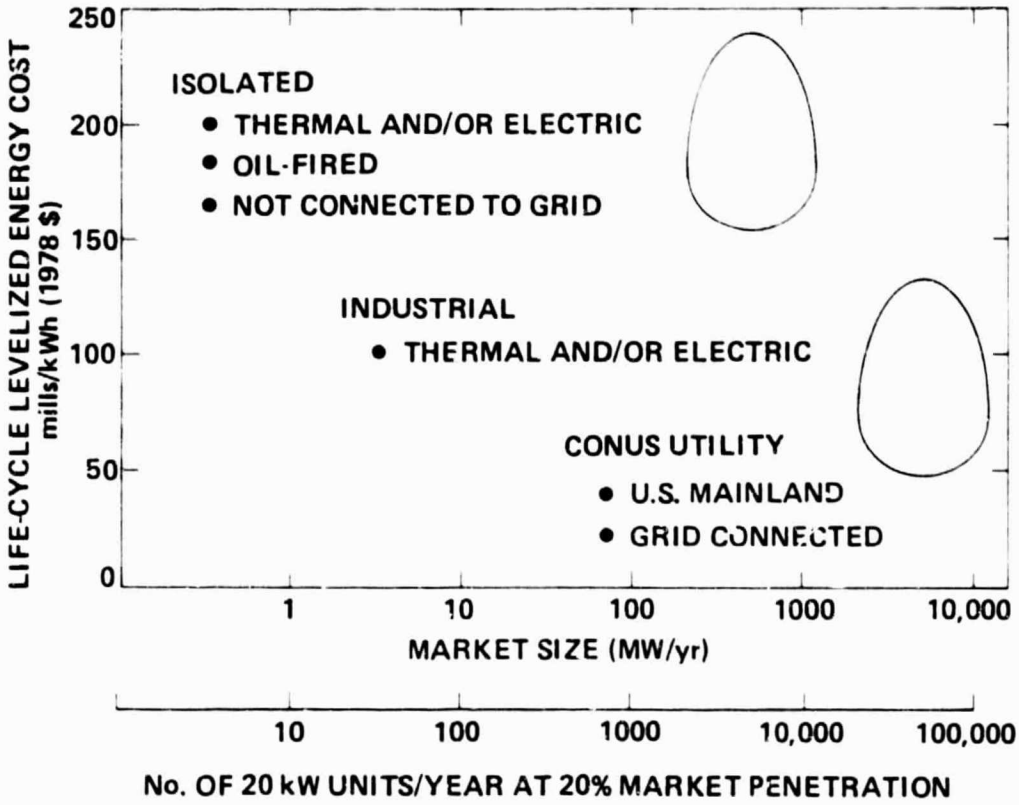

Figure 3. Energy Cost and Market Size

Conversations with representatives of utilities located on Pacific islands reveal that fuel costs early in 1979 were $18.50 per barrel and diesel generator installed costs were $600/kW(e) resulting in 1979 levelized bus bar costs 120 mills/kWh.1/ Clearly the remote utility application is a significant early market for dish collector electric power plants. As shown in Figure 3, the projected size of this market in the 1990-2000 time period is 300 to 1000 MW/year. Although this market is small in comparison to the grid connected utility market, the graph also indicates that by assuming only a 20% market penetration, up to 10,000 power modules per year would be required to meet this need. Such a high production level would clearly justify the use of mass production manufacturing techniques.

In the long run, the major electrical market is the U.S. grid-connected utility market which is referred to in Figure 3 as the CONUS (continental United States) utility market. Each power plant in the grid is backed-up by the balance of the utility's generation and transmission capability. In 1974 the Southwestern U.S. utilities' generating capacity was about 46,000 MWe. Almost all utilities in the continental U.S. are grid-connected, or will be by the 1980's. Using conservative estimates of availability and prices of conventional fuels, it is projected in Ref. 2 that levelized bus bar energy costs ($\overline{BBEC}$) for new plants operational in the 1990 time period will range from 50 to 70 mills/kWh for base load coal-steam plants, and up to 200 mills/kWh for oil-fired intermediate and peaking plants.

In addition to the electric market, both grid and non-grid connected, there exists a large market for a combination of both thermal and electric power. Industrial process heat is a typical application in this category. Eventual penetration of this market should expand the use of the parabolic dish system significantly.

In summary, it is clear that to build manufacturing volume most expeditiously, the high cost, isolated load markets should be penetrated first.

---

1. Based on a capacity factor of 0.6, system life of 30 years, a fuel escalation rate of 3% above inflation, and an annualized fixed charge rate of 0.157.

To compete in the low cost grid-connected market will require both experience and production volume which can result from the successful prior pursuit of the higher cost, isolated markets.

4. Concept of First and Second Generation Technology

From a technology standpoint, the project strategy is to first develop hardware suitable for entering the near-term isolated load market. First generation equipment, based on gas turbine technology, will entail less development risks and permit the early introduction of solar plants into the marketplace. Satisfying the demands of the near-term market will help to mature all the infrastructures essential to solar power plant sales, especially with regard to collectors. Just as importantly, this strategy will also make solar power plant technology more visible and thus encourage its large-scale use in other applications.

To meet the long-term goal of the project (i.e., entering the grid-connected market with baseload coal-steam and nuclear plants), improved system efficiency is needed. This will be achieved through use of advanced engine (second generation) technology. Additional cost reductions are expected from continuing improvements in dish collector design, and through increased production.

Solar power plants produced from first generation technology have system goals of 100 to 120 mills/kW hr. Such plants can compete with conventional systems in the near term isolated load market, and in the oil-fired, intermediate-peaking, grid-connected market, but will need to be improved for the baseload grid-connected power plant market. The main attraction of these plants is that they will enter the near term market, develop the required infrastructure and require only a modest R&D investment by the government to mature.

Power plants using second generation dish technology will require more time to bring on line (3 to 4 years of additional technology development) and consequently will require more resources to develop. Work on second generation systems has already begun. These plants have system cost goals ($\overline{BBEC}$) of 50 to 60 mills/kWh, which are clearly competitive with coal and

nuclear systems in the grid-connected market. Utilizing the above costs for electricity, cost targets have been developed for both first and second generation subsystems hardware. These are shown in Table 2.

5. Component Cost Projections

Some progress has already been made in studying the attainability of the cost goals presented above. Preliminary studies have been completed on the two major subsystems of the power plant, i.e., the dish concentrator and the power conversion unit. Concentrator costs are important due to their dominance in power plant costs, and due to their amenability to the mass-production process. Studies are under way both at JPL and by industry to assess the effect of mass production in reducing dish concentrator costs. Manufacturing techniques and tooling requirements are being studied to develop a basis for estimating capital equipment costs and the production costs of dish concentrators. As an example of this work, estimates of the reduction in concentrator costs as the annual production rates increase are shown in Figure 4. The estimates were made for JPL by four different industrial contractors. The encouraging result from these studies is that the first generation concentrator cost targets are easily met at production rates as low as 10,000 units/year. These projections represent total installed costs for the concentrator. Figure 5 displays the cost range of the four contractors for each of the major concentrator subsystems for a production rate of 100,000 per year.

Production studies have also been performed by industry for small engines such as gas turbines, Rankine turbines, Stirling engines and industrial diesel plants. A composite of these results is presented in Figure 6. As may be seen, at 25,000 units/year engine/generator costs are about 160 $/kW.

6. Projected Power Plant Bus Bar Energy Costs

Estimates of levelized bus bar energy costs from dish-electric power plants have been made based on projected component performance and costs. The results of these studies are presented in Figure 7 as a function of

TABLE 2. COST AND PERFORMANCE TARGETS FOR ELECTRIC POWER GENERATION (1978 DOLLARS)

SUBSYSTEM	PARAMETER	TARGETS FOR FY	
		1ST GENERATION (1982)	2ND GENERATION (1985)
CONCENTRATORS	COST IN MASS PRODUCTION*	$100 – 150/m^2	$70 – 100/m^2
	REFLECTOR EFFICIENCY	90%	92%
RECEIVERS	COST IN MASS PRODUCTION*	$40 – 60/kWe	$20 – 40/kWe
	EFFICIENCY	80%	85%
POWER CONVERSION	COST IN MASS PRODUCTION*	$200 – 350/kWe	$50 – 200/kWe
	EFFICIENCY	25 – 35%	35 – 45%

* RANGE OF 1ST GENERATION PRODUCTION: 5,000 - 25,000/YEAR.
* RANGE OF 2ND GENERATION PRODUCTION: 10,000 - 1,000,000/YEAR.

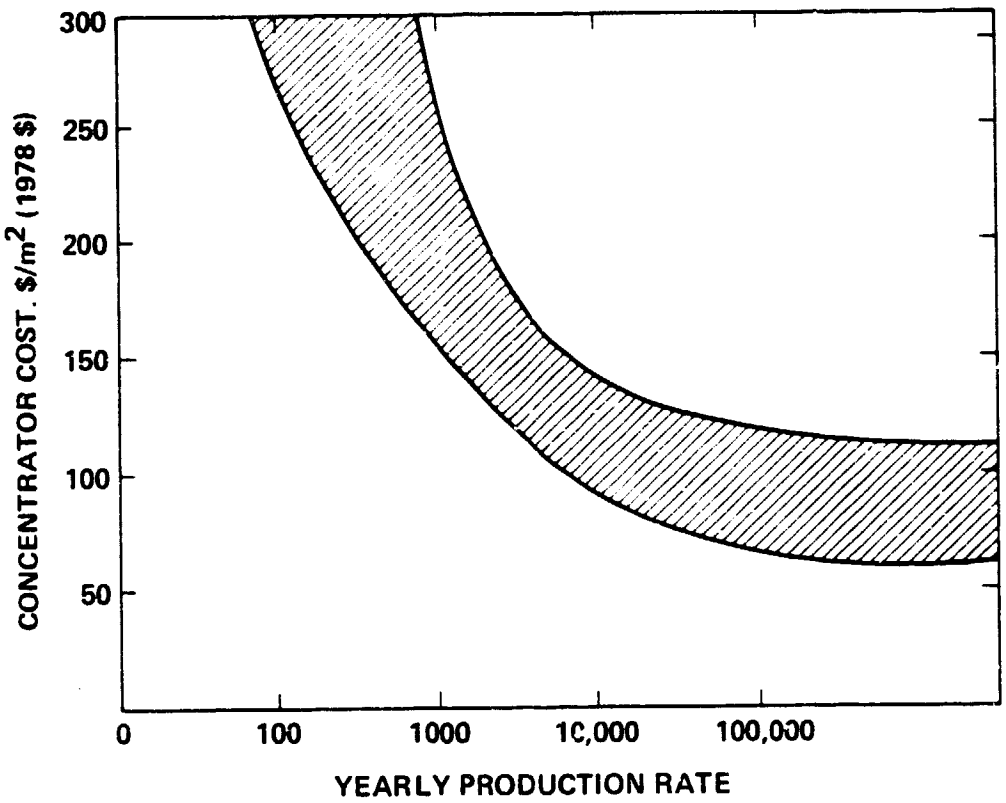

Figure 4. Concentrator Costs Based on Contractors' Estimates

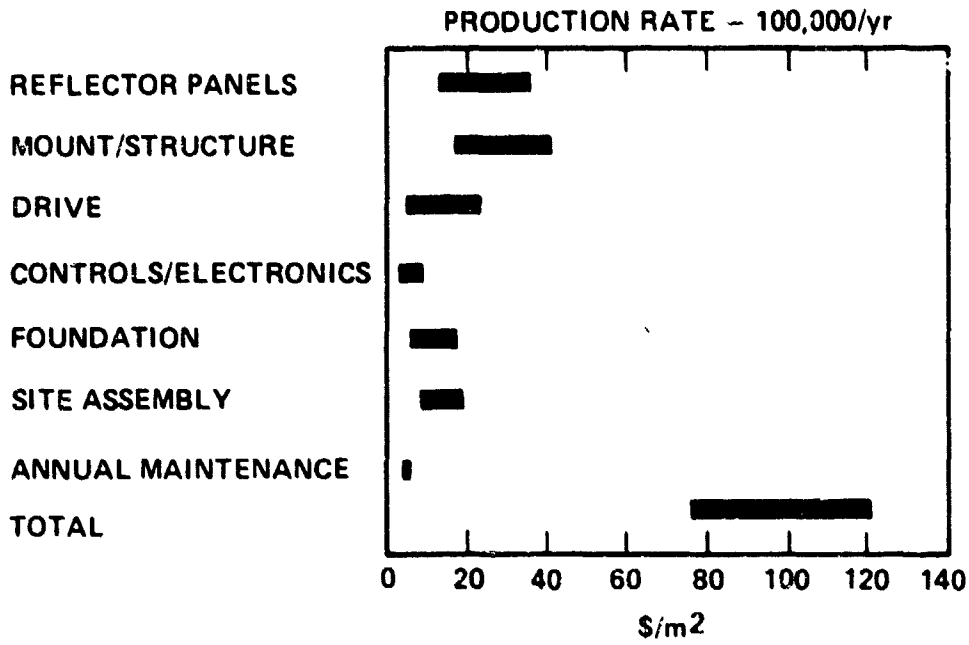

Figure 5. Sub-Element Costs of Concentrators (First-Generation Technology)

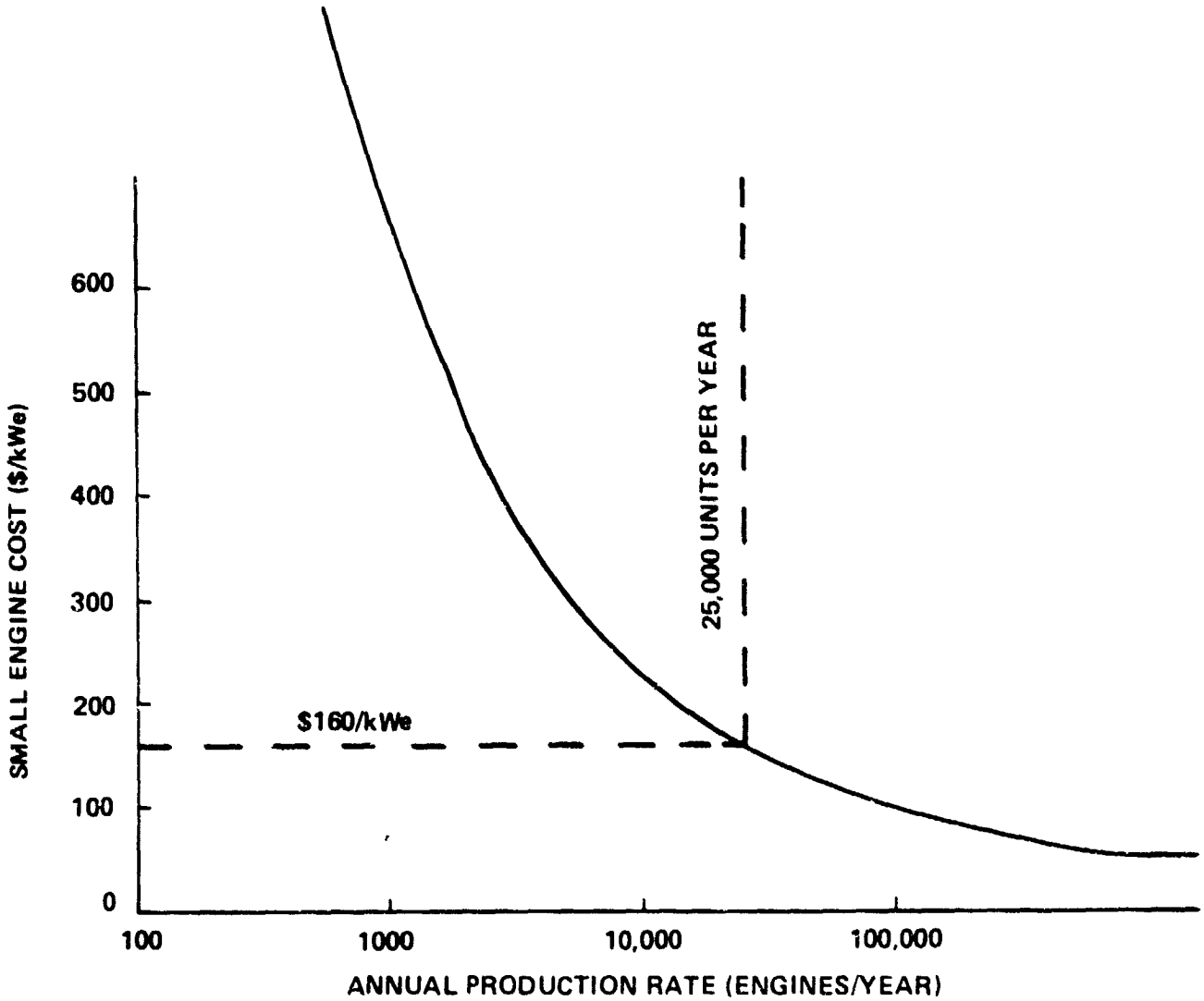

Figure 6. Effects of Mass Production on Small Engine Cost

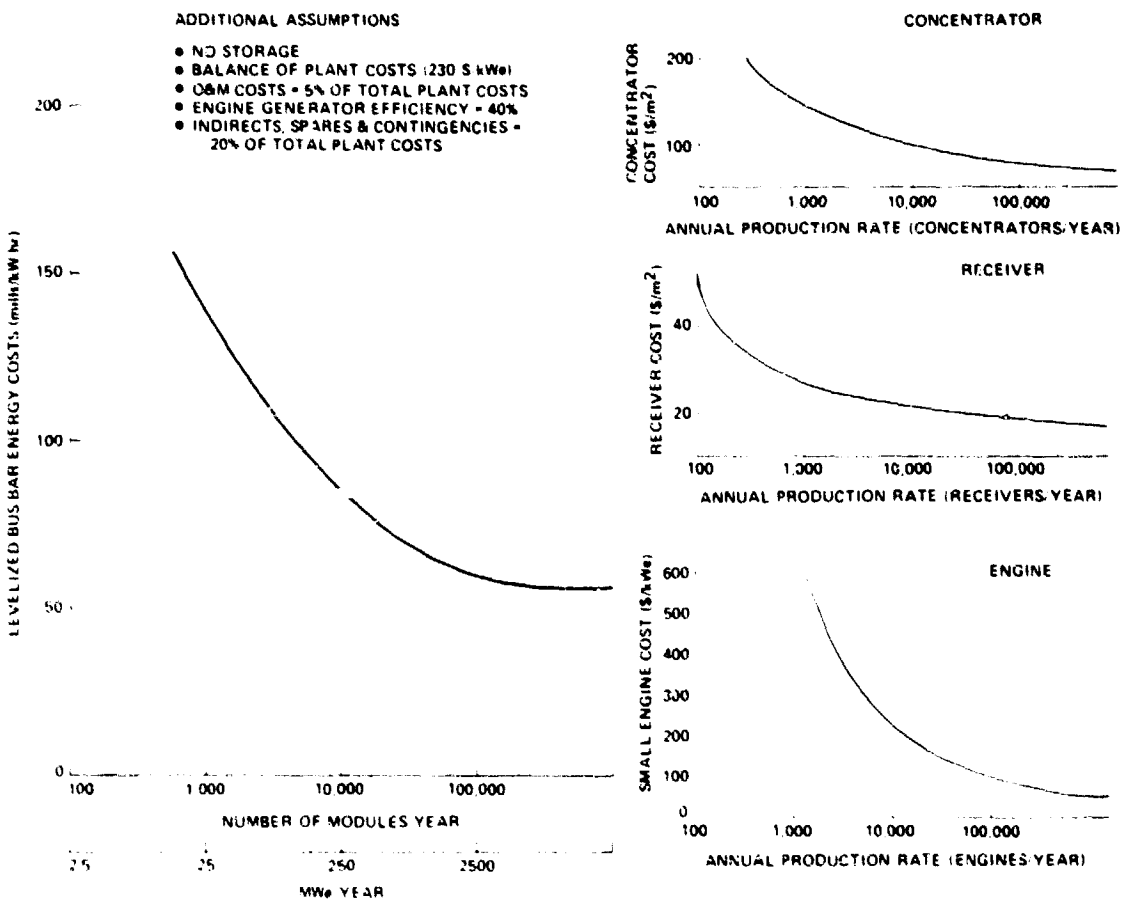

Figure 7. Effects of Mass Production on BBEC

the number of dish power modules (25 kWe peak) produced per year. Information is presented in this fashion since power module cost is a strong function of the collector and engine costs which are in turn affected by the production rate. Figure 7 also indicates the assumed costs for the basic module components (concentrator, receiver and engine) in various production rates, and the assumed balance of plant and O&M costs. At a production rate of 25,000 units/year and assuming no energy storage, levelized bus bar energy costs of 75 mills/kWeh are projected (1979 dollars). These numbers are based on what is believed to be a conservative estimate regarding engine-generator conversion efficiency (40%) for the 1990 time period. With a more optimistic estimate of efficiency (i.e., 45%), the bus bar cost decreases to about 67 mills/kWeh. At very large production rates (400,000 modules/year), the costs decrease to 58 mills/kWeh. Clearly such costs permit penetration of the grid-connected utility market.

7. Project Strategy and Status

The TPS project goal is to demonstrate technical, operational, and economic readiness of PFDR technology for electric and thermal power applications. To reach this goal in a timely manner, the project has three parallel but complementary activities or elements as shown in Figure 8. Advanced Development is R&D oriented, with emphasis on feasibility testing and component and materials development. Advanced designs from this activity are utilized by the Technology Development element which does the detailed engineering and fabricates and validates (tests) a complete module (concentrator, receiver and engine).

The third element of the project, Applications Development, is responsible for developing complete power plant system and demonstrating the technology through a series of engineering experiments sited in a variety of potential user environments. The status of each of these three project elements is described below.

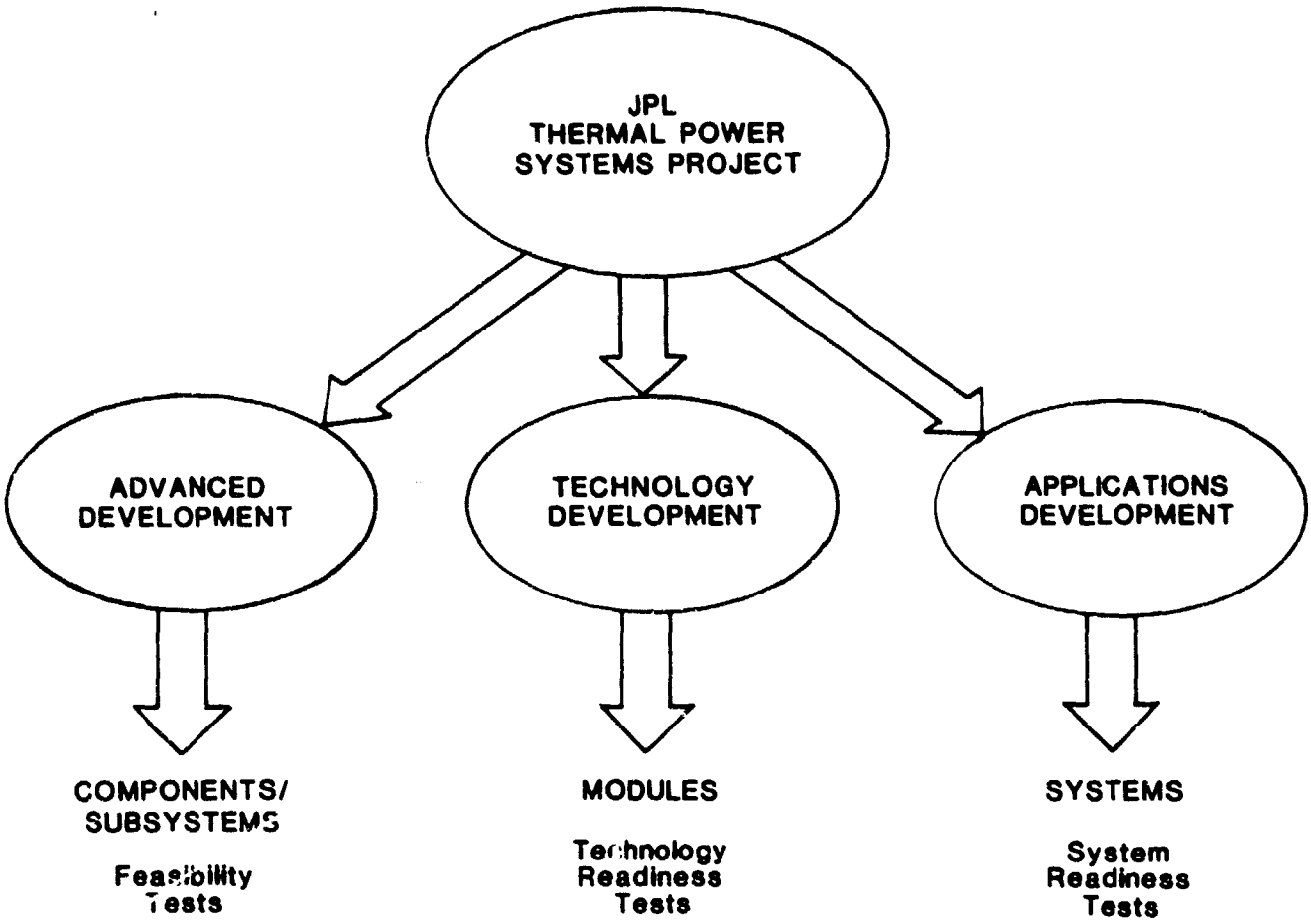

Figure 8. Interrelationships Between TPS Project Elements

7.1 Technology Development

The present thrust of this project element (Ref. 3) is to develop first generator subsystems (including concentrators, receivers/transport and power converters) which can be utilized in the Applications Development element for engineering experiments. The major products of this project element are illustrated in Figure 9.

First generation hardware emphasizes proven gas turbine technology for the power conversion equipment, and an injection molding process for fabrication of the plastic petals or gores for the dish concentrator structure. This manufacturing technique already exists and is used in the production of a number of commercial products such as refrigerator doors. It should facilitate the attainment of mass-producible, low-cost contractors. A first-generation dish concentrator being developed by General Electric and configured for injection molding is shown in Figure 10. Similarly, existing small gas turbine technology, very much like that developed for automobile turbochargers, cruise missiles, torpedoes, and auxiliary power units, is being studied for the eventual mass production of power conversion subsystems. The first-generation engine and receiver, presently being developed by Garrett Corporation, is shown in Figure 11.

The schedule of Figure 12 shows the flow of design, fabrication and test activities for both first- and second-generation hardware leading to two key events: a Brayton module on test in mid CY 1981, and a Stirling module on test early in CY 1984. The subsystems involved are concentrators, receivers, and power convertors. Second generation subsystems will be selected for incorporation in the Technology Development element of the project on the basis of the status of competing concepts emerging from the Advanced Development work described below.

Testing and evaluation of these dish power modules are performed at the JPL desert test site shown in Figure 13. Evaluation of early dish hardware is already taking place at this site. A 6-meter diameter dish module purchased commercially from the Omnium-G Company of Anaheim, California has been under evaluation at the test site since early 1979. By September 1979, an 11-meter dish designed and constructed by E-Systems of

PRODUCTS FROM TECHNOLOGY DEVELOPMENT

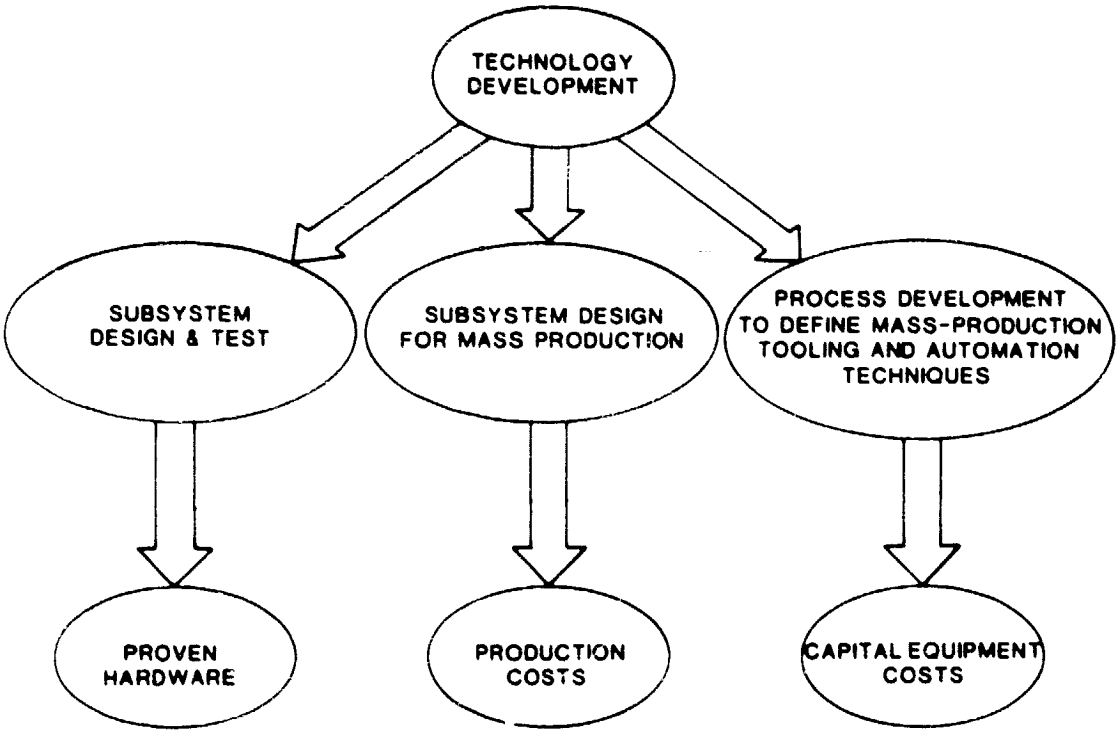

Figure 9. Products From Technology Development

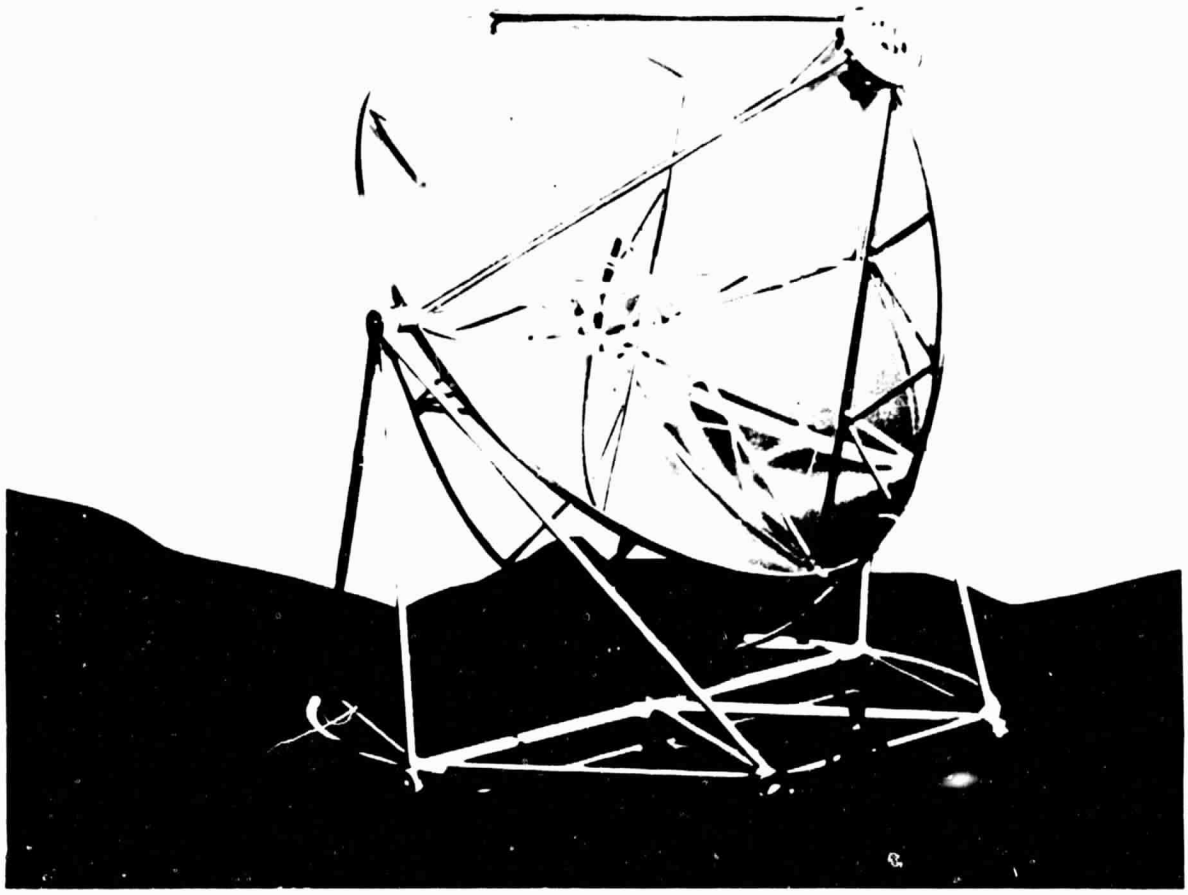

Figure 10. General Electric Low-Cost Collector Concept

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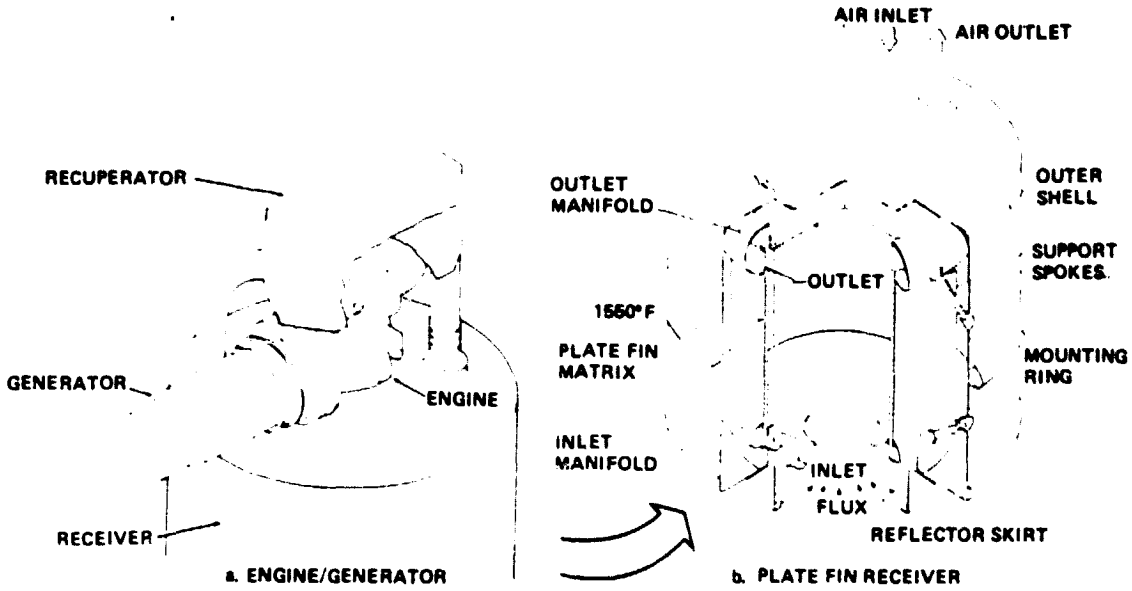
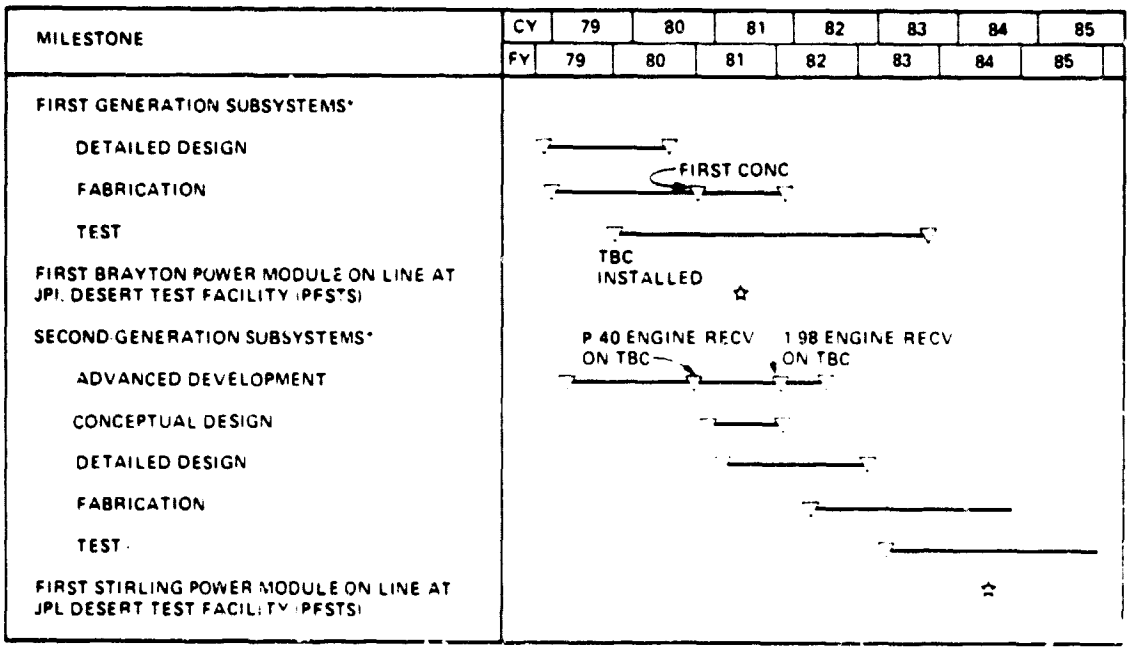


Figure 11. First-Generation Brayton Engine/Generator and Receiver



*CONCENTRATORS RECEIVERS AND POWER CONVERTERS

Figure 12. Technology Development Schedule

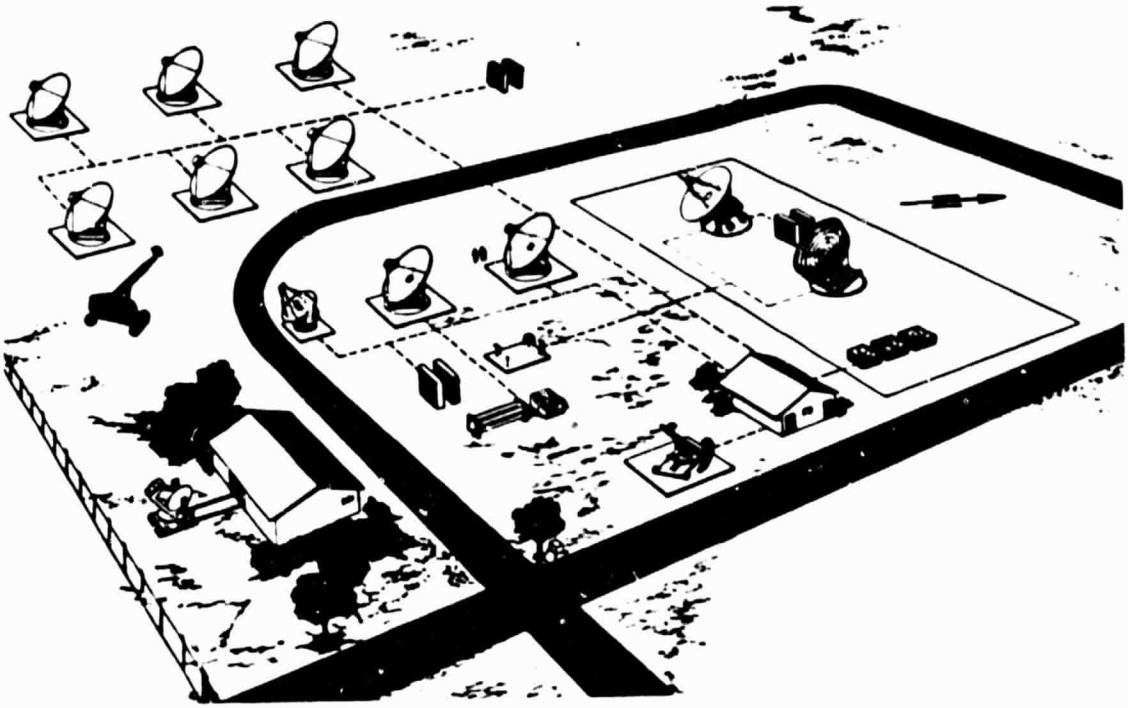


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Figure 13. JPL Desert Test Site (PFSTS)

Garland, Texas, will be under test and evaluation at JPL. It is called a test bed concentrator (TBC) and will be used to test and evaluate receiver and engine units prior to installation on either first or second generation concentrators for full power tests. The Omnium-G module and the Test Bed Concentrator are shown in Figure 14.

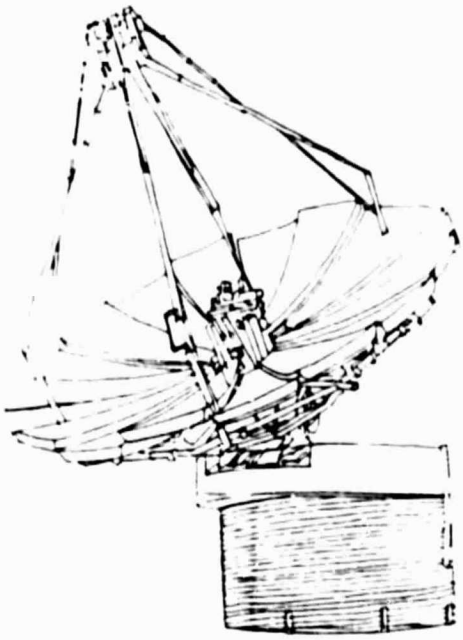
Earlier dish hardware developed under a Sandia-Albuquerque (SLA) program is shown in Figure 15. One unit was developed for SLA by the Raytheon Corporation, the other by General Electric. Both of these units are limited to temperatures of about 600°F. The general Electric unit was designed for use in a total energy application at Shenandoah, Georgia.

7.2 Advanced Development

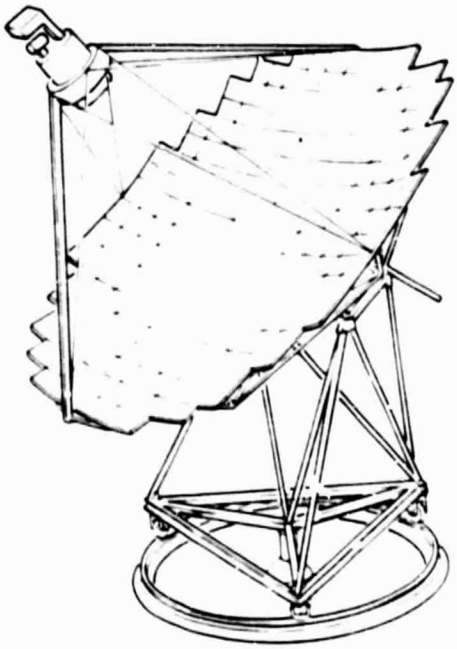
The work of this project element is directed to the development of materials and dish subsystems which meet the cost and performance goals of second and subsequent generation dish power plants. Example components are cellular glass monolithic gores for concentrators; both heat pipe and non-heat pipe hybrid high-temperature receivers for both power conversion and high temperature thermal applications; thermal transport and buffer storage; and under LeRC technical management, both free piston and kinematic Stirling engines for power conversion. This advanced work is in direct support of the Technology Development effort described previously.

Most of the work is accomplished directly through subcontractors to JPL and LeRC. The work falls in two categories, that done under DOE program management and the remainder which is done under SERI program management as shown in Figure 16. Highlights of the work in progress are shown in Figure 17.

An important part of the Advanced Development effort is the development of second-generation point focusing components (Ref. 4). The main thrust regarding engine concept is the Stirling engine although consideration is also being given to high temperature Brayton engines (2000°F), and/or combined-cycle engines (which combine Brayton and Rankine technologies). Work for JPL on a Stirling engine and receiver is underway in a joint effort between Fairchild Stratos and United Stirling of Sweden (USS)

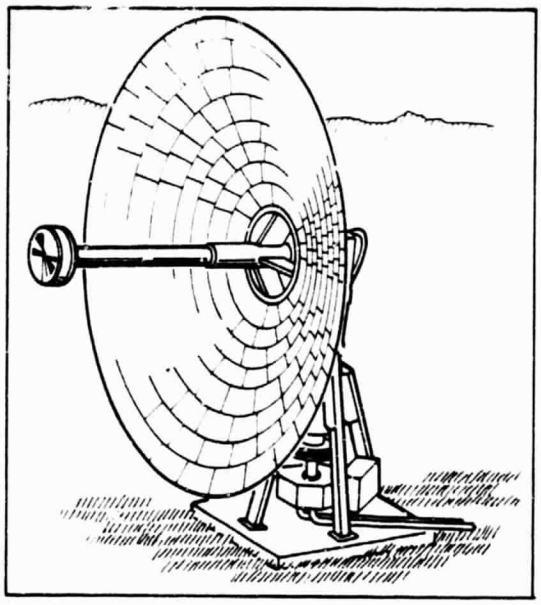


OMNIUM-G CONCENTRATOR

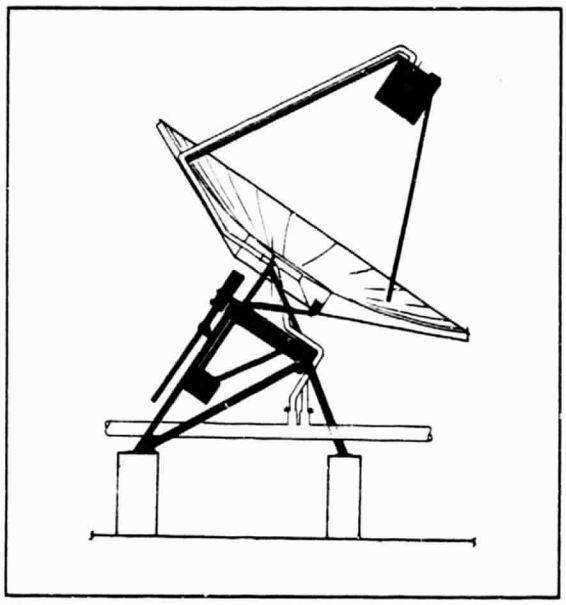


JPL TEST BED CONCENTRATOR BY E-SYSTEMS

Figure 14. Current Technology Concentrators



a. SLA TEST DISH COLLECTOR
BY RAYTHEON



b. SHENENDOAH DISH COLLECTOR
BY GENERAL ELECTRIC

Figure 15. Early Technology Concentrators

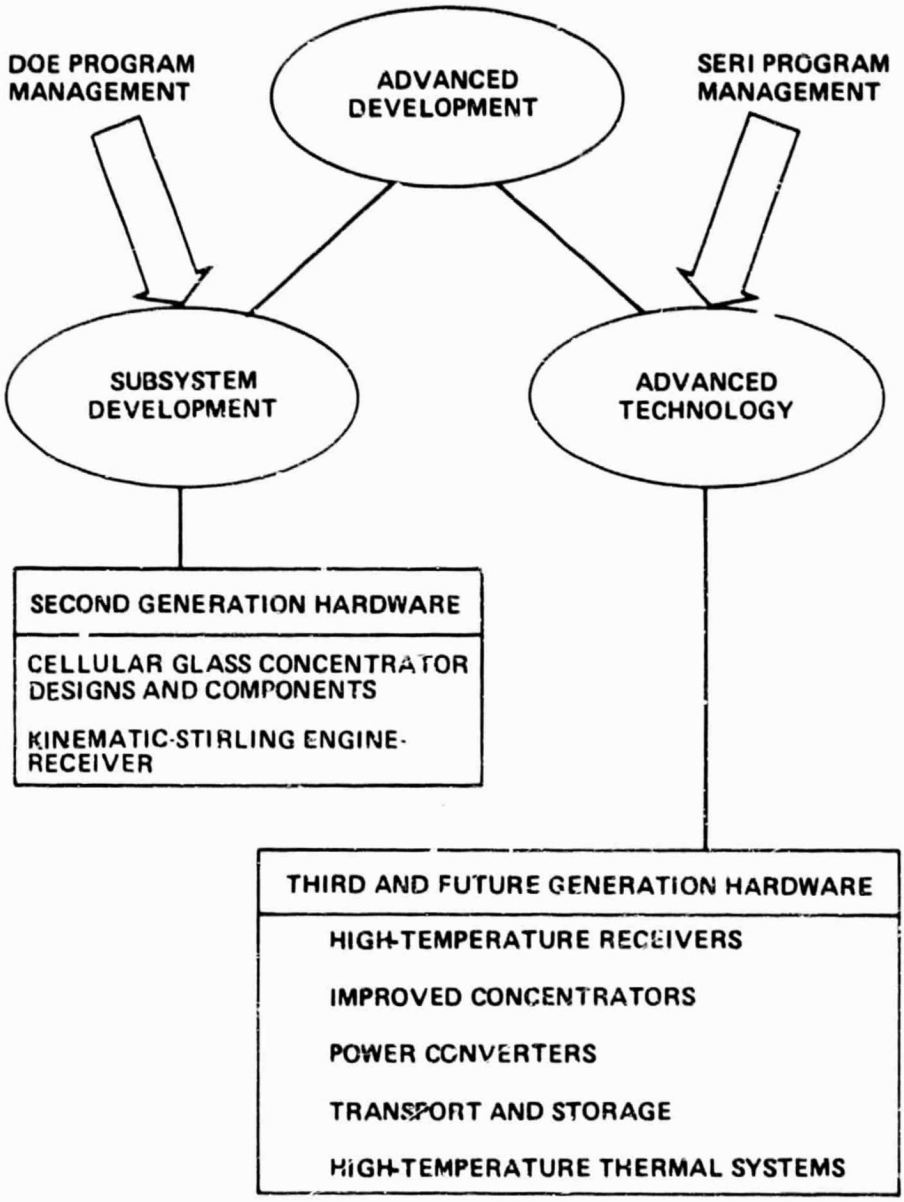


Figure 16. Advanced Solar Thermal Development Program

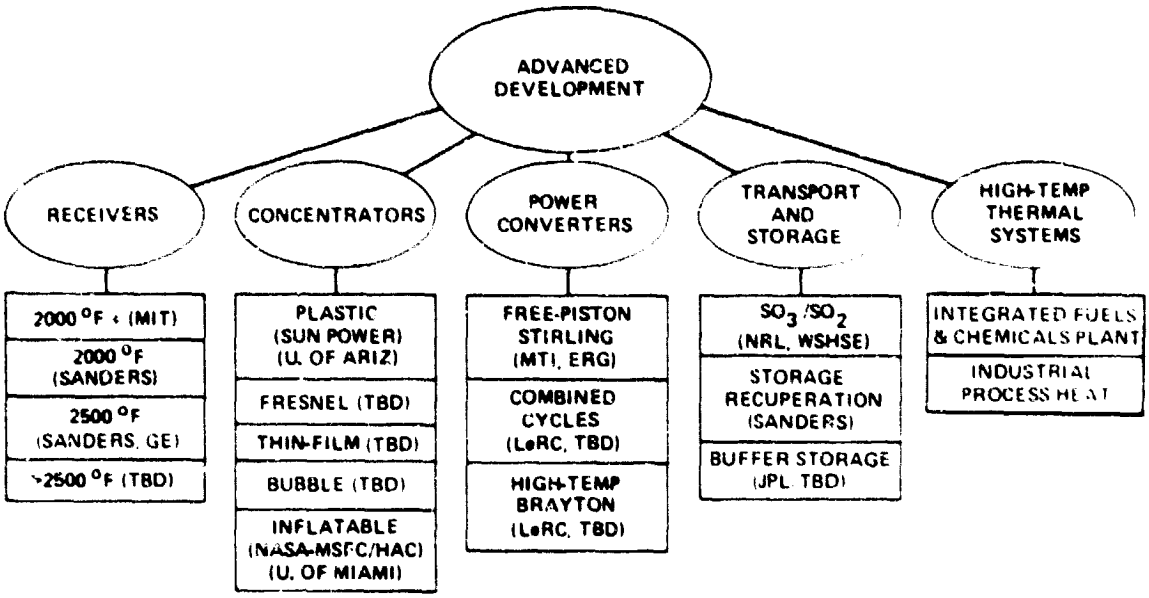


Figure 17. Highlights of the Solar Thermal Subsystem Development

based on the USS model P-40 engine. As noted in Figure 12, the P-40 engine/receiver module will be placed on test at the JPL desert test site (mounted on the test bed concentrator), near the end of CY 1980. It will represent the first technology demonstration of a solarized Stirling engine and will define control and other potential engineering problems associated in the integration feasibility of an engine with a solar/receiver. This test will be followed by a similar demonstration with the GE/North American Phillips 1-98 engine/receiver module about a year later.

7.3 Applications Development

The third project element is concerned with market applications of dish systems (Ref. 5). Implementation of engineering experiments in various user environments is the major activity of the Applications work. It has the goal of demonstrating technical, operation, and economic readiness of dish systems in both electric power and process heat applications. The experiments are identified in terms of market sector in Figure 18. Three series of experiments have been defined, each related to a different market sector. These three series of experiments are described below. A schedule for the near-term experiments in these series is shown in Figure 19.

EE No. 1 is known as the "Small Community Solar Thermal-Power Experiment," and is one megawatt in size. As noted in Figure 18, it looks toward the grid-connected market of the continental United States. Because this market is as important as it is difficult, work is under way through EE No. 1 to gain early experience in that highly competitive market. It is scheduled to be on-line in early CY 1983. The systems contractor will select the power converter but the collector will be first-generation technology as developed by the Project.

EE No. 2 is known formally as the "Isolated Application Experiment Series," and addresses island sites, rural electrification in foreign countries, and other applications remote from the grid. Plant sizes will be about 100 kilowatts (electrical). A joint effort is now under way with the Navy Civil Engineering Laboratory on a co-funded basis. The EE No. 2a

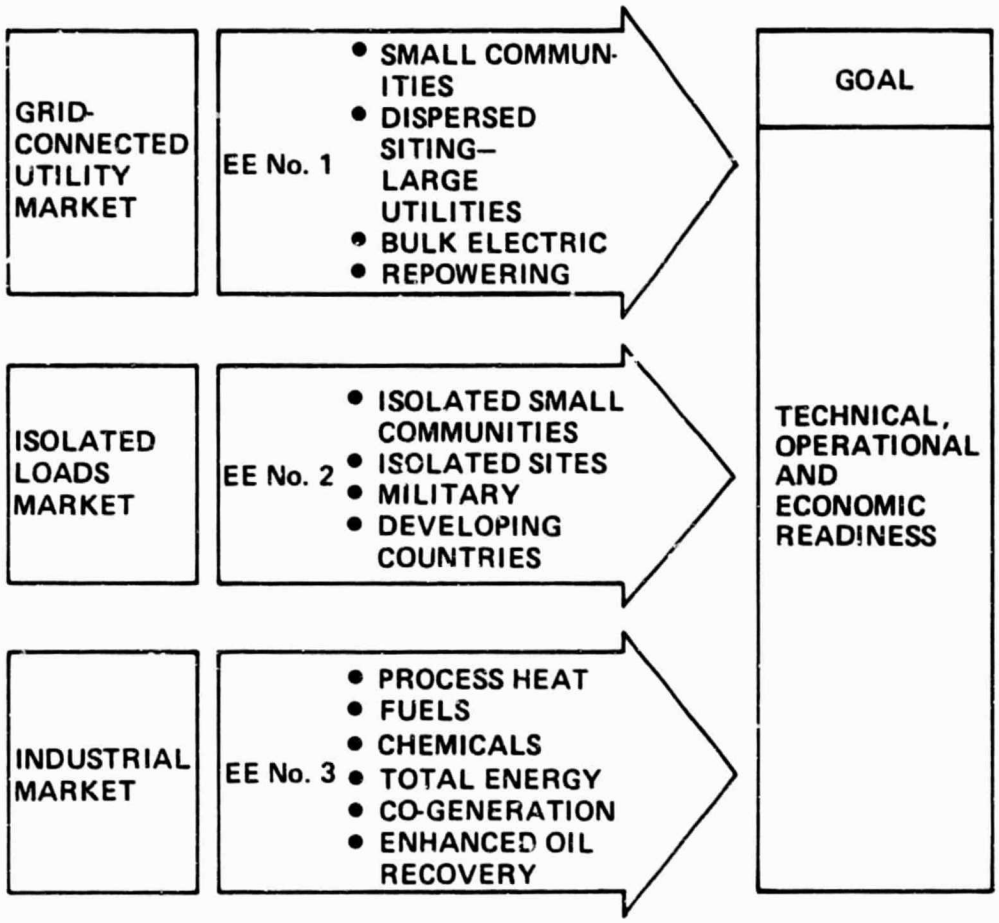


Figure 18. Engineering Experiments

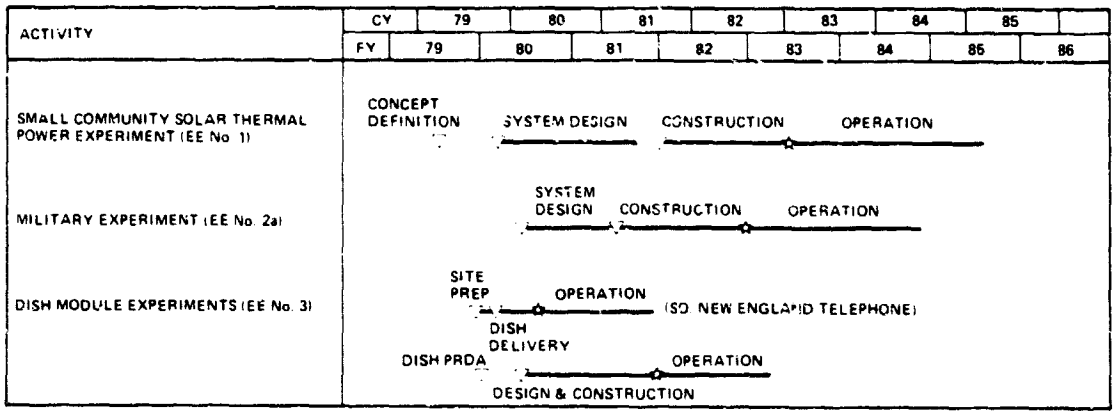


Figure 19. Schedule for Near-Term Application Experiments

power plant will use receivers of hybrid design, and Brayton power converters. EE No. 2a is the first of the series, and is scheduled to be operational in late CY 1982.

The EE No. 3 series, addressing the industrial market, will initially be implemented through a series of very small experiments (less than 20 KWe) for thermal, electric and combined (cogeneration) applications.2/ These small experiments will be conducted using available hardware to the maximum extent possible. Because they are small they can be constructed and installed in a very short time. Although not a direct product of the JPL program, an example of such an experiment is the ongoing effort cofunded by DOE and the Southern New England Telephone Company for an industrial cogeneration application, using the Omnium-G power module. The primary function of this power unit is to produce electricity for a switching center, but excess power will be used for space heating and for absorption cooling. The unit is to be operational early in CY 1980. A number of other units of this class are scheduled by JPL for operation in CY 1981.

Experiments in all three series will follow an improved technology path with each new experiment utilizing the then current state-of-the-art dish-engine technology.

Studies supporting these experiments are being conducted in-house and by contractors and include costing, market penetration, industrialization, mass production, and systems design requirements as a function of application. A requirements analysis being performed by Science Applications, Inc., a market penetration study by General Electric, and an industrialization study by Arthur D. Little are examples of currently contracted activities. Site selection criteria studies and market definition studies are representative of in-house work.

For EE No. 1 (the small community experiment) the site selection process is under way, and for EE Nos. 2 & 3 the various sites are to be selected during CY 1980. The site selection activities are the responsibilities of DOE although JPL will assist in the process.

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2. As of this writing, DOE has not yet officially approved initiation of this series for FY-80, and thus it may be delayed until FY-81.

When the experiment sites are selected, the applications oriented work will become heavily involved with integration of the multiple interfaces represented by the community, the local utility, and the systems contractor. This phase of the project will be its first operational phase and will provide direct indication of the extent to which dish technology is meeting its operational goals, and will reveal the extent of market penetration that can be expected of subsequent second-generation technology.

8. Acknowledgement

In writing this paper, the authors have borrowed from the work of many solar thermal investigators at JPL and the NASA/Lewis Research Center. The contribution of Steve Bluhm and Bill Revere of JPL are particularly noted.

9. References

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2. "Electric Energy Costs of Southwestern U.S. Utilities to the Year 2000," C. Davis and R. Gurfield, JPL Internal Document 5103-62, April 1979.

3. "Solar Thermal Power Systems Point-Focusing Distributed Receiver (PFDR) Technology: A Project Description," J. W. Lucas and J. Roschke, AIAA/ASERC Conference on Solar Energy: Technology Status, Phoenix, AZ, November 27-29, 1978.

4. "Solar Stirling System Development," J. W. Stearns, et al., AIAA Terrestrial Energy Systems Conference, Orlando, FL, June 4-6, 1979.

5. "Solar Thermal Power Systems Point-Focusing Thermal and Electric Applications Project: A Progress Report," A. T. Marriott, 1979 International Congress, Atlanta, GA, May 28 - June 1, 1979.

The following questions were then directed to and answered by Dr. Truscello of J.P.L.:

Q. "Does the paper address the estimated O & M costs under given environmental conditions?"

A. "This topic is covered only very loosely."

Q. "Have relative O & M costs for the various technologies been established?"

A. "More work has been done in this area during the past few months. We are not sure if the Brayton engine will have lower O & M costs than the Stirling although the Brayton probably has a much longer life span. Much attention is being paid to this subject. The O & M costs overall are very similar. Although the Stirling engine may have maintenance costs as much as three times the estimate for a Brayton, the higher efficiencies associated with the Stirling engine show it may be superior to the Brayton in terms of second generation technology."

Q. "What considerations have been made for the maintenance of components such as reflectors, etc., that are independent of the generator system?"

A. "Fortunately, much of this work is being done through other programs sponsored by DOE. For example, our O & M requirements for clean mirrors will parallel those associated with heliostats and the large power program DOE has. Therefore, we will tap off those programs to the maximum extent possible. We will take care of any additional peculiar things which we think require specific attention. We do feel that the government has a pretty good handle on these costs already. One thing they are finding out is there can be too much cleaning.

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Sandia, Albuquerque has done a considerable amount of work in defining the optimum cleaning process."

Q. "At what frequency are these systems operational?"

A. "They can be designed for any frequency, but 60 Hz will probably be our standard."

Q. "How does one regulate phase, etc., in order to put these systems on a grid?"

A. "An integral part of the power plant will be the power conditioning and regulating system. System selection will depend on application specific factors which are a lot more technical than I am prepared to answer at this time."

Q. "What is the working fluid in this Stirling engine?"

A. "This is a closed cycle system so helium is the working medium. For the Brayton, the working medium is air. Additionally, we are looking at more advanced closed loop Brayton systems that use helium-argon mixture. These systems have the potential to be more efficient and compact."

Q. "The integration of these systems with alternate fuels has been mentioned. Does this mean that these fuels will be used with the Stirling and Brayton engines or with more conventional auxillary engines?"

A. "The fuel will be used with the Stirling and Brayton engines. This is possible since the gas or oil burners are an integral part of either the receiver or the engine. In the case of the Brayton turbine system, the burner system is already in place and we are simply

attaching the thermal receiver. When solar radiation is not available, the turbine is fired by gas or oil combustion. In the case of the Stirling Engine, the alternate fuel is utilized through combustion within the receiver itself."

Q. "It was mentioned that another conference which would emphasize remote small dish industrial applications would be held in the near future. What is the tentative date for this?"

A. "It would probably be held in October or November of 1980."

Q. "If there is to be an industrial program by next year, what is being accomplished in the area of heat sinks (thermal storage)?"

A. "The incorporation of thermal storage systems was not covered in this paper. For process heat, the systems would be entirely different. Heat engines would not be placed at the focal point. Rather, the collective system would consist of networks of transmission lines from dish to dish that transport the thermal energy to a central storage position. The government is supporting the development of thermal storage systems."

Q. "What branch of the government is supporting research in thermal storage?"

A. "The branch is called STOR. STOR deals with many programs which involve the storage of heat, including solar and geothermal applications."

GUEST SPEAKERS

DOD ENERGY MANAGEMENT

George Marienthal
Deputy Assistant Secretary of Defense
(Energy, Environment & Safety)

I. INTRODUCTION

It's a real pleasure to be here this morning and help you kick off your workshop for potential military and civilian users of small solar thermal electric power technologies.

This workshop is a real milestone. It is the first workshop that DOE has helped sponsor which has looked to the Department of Defense early in a technology development phase so that our application requirements could influence systems design. We appreciate it.

This type of cooperative effort between DOD and the Department of Energy has and will produce significant benefits for each of our organizations. We recognize that technology efforts are denoted to specific applications. DOE's R&D is often more general, but we can help give some focus to DOE's programs and provide a testbed for demonstration of energy technology applications.

We encourage working level cooperation between our laboratories and the national laboratories. They will benefit our own missions and will contribute significantly to the realization of the President's energy goals.

I am especially pleased to speak to all of you, because we are very much interested in small scale energy systems which will promote energy independence and reduce our reliance on local utility systems.

As you all know, we have established a military standard family of mobile electric power generators to satisfy many of our specific requirements for remote power needs.

MERADCOM is our program manager for this effort and has done a splendid job over the last five years in this capacity.

Standardization of military mobile electric power generators is indeed in the best interest of availability, interchangeability of parts, maintainability, and reduced logistic support.

Even with our emphasis on standardization, we believe that the application of new energy technologies will help to satisfy our enormous appetite for energy--especially for our remote and portability needs.

Energy technology demonstration is important to the Department of Defense and to the nation's energy program as well. I will describe our energy technology demonstration effort in a little greater depth in a few minutes.

To discuss energy in the context of my responsibilities for energy, environment, and safety, I'll answer your question before you ask it. Management of energy, environment, and safety is quite compatible. Their programs, while mutually exclusive, often lend support to one another.

II. OVERVIEW

Our energy program is aggressive and well balanced. My following remarks will give you an overview of:

(1) How defense energy resources are managed at the DOD policy level;

(2) How we are organized and how our management structure is integrated with the military departments;

(3) How our energy program dovetails with Department of Energy programs;

(4) What our goals and objectives are;

(5) What our programs are to achieve them; and

(6) What our long-range plans are to assure a continued energy supply under all circumstances.

III. DOD ENERGY MANAGEMENT

Our energy organization is decentralized, but it is functionally structured to handle energy contingencies, develop energy policy, and design long-range energy plans and programs.

While my office serves as the focal point for all DOD energy matters, specific energy program managers include:

(1) DLA/DFSC for bulk POL procurement,

(2) DASD (I&H) for military construction & ECIP,

(3) DUSDR&E (R&AT) for energy research and development, and

(4) DUSDR&E (AP) for GOCO conservation programs.

DOD energy policy is coordinated through the DEPC senior level policy council comprised of:

(1) OSD principals,

(2) Military departments (Spec. Ass'ts. for Energy.)

(3) JCS (Director, J-4)

(4) DLA/DFSC (Director, DLA and Commander, DFSC).

We have assigned lead service responsibilities to the military departments for key energy technologies to:

(1) Enhance energy management,

(2) Ensure better coordination, and

(3) Provide a means for technology transfer.

I will cover this lead service concept a little more in depth later.

IV. SCOPE OF DOD ENERGY PROGRAM

While we use tremendous amounts of energy--80 percent of all federal consumption--we rely heavily on petroleum. Petroleum accounts for nearly 70 percent of defense energy consumption. Last year, we used 252 billion barrels of oil equivalent. 170 million barrels were petroleum. The Air Force was the biggest user at 57 percent. Navy and Marine Corps used 33 percent, and Army used 10 percent.

Operationally, our energy usage looks like this:

- Aircraft operations is our biggest--last year's use was 113 million barrels alone.

Our energy is expensive. Last year we paid more than four billion dollars for it, and we estimate that it will cost nearly six billion in 1985. This estimate may be quite conservative, however.

DOD's consumption since 1973 has decreased 30 percent while the costs have continually increased. Last year DOD reduced energy consumption nine percent under FY 1975, the baseline year for measuring energy conservation in the federal government.

(1) 12 percent mobile operations, and

(2) 4 percent in facilities.

V. MANAGEMENT GOALS AND OBJECTIVES

We have divided our goals and objectives into two groups:

(1) Supply, and

(2) Conservation.

Our supply and conservation goals cover both installations and mobility operations. These are our installation energy supply goals. They cover the use of more plentiful energy resources and alternate fuel capabilities for our facilities.

Our mobility goals are designed to:

(1) Minimize supply disruptions and,

(2) Achieve capability to use a greater range of fuels.

Our installation energy conservation goal is to achieve a 20 percent energy reduction in our existing buildings by 1985. We plan to do this with:

(1) ECIP ($1.5 billion retrofit program), and

(2) Other efforts (ECMS, energy awareness, etc.).

For mobility operations, we will limit our operational energy use to what we used in 1975. We will do this with:

(1) More efficient propulsion systems,

(2) More efficient use of equipment, and

(3) Greater use of simulators.

VI. 1979 ENERGY PRIORITIES

We have divided our 1979 goals into four priority groups, or bands, of action.

(1) Priority Group I

(a) This covers the formulation of management and regulatory mechanisms with DOE to assure essential defense fuel requirements are met during periods of supply disruption--we are doing this now. We are working closely with DOE and developing an energy emergency management system.

(2) Priority Group II is the energy R&D plan for mobility fuels.

(a) OUSDR&E, under our overall management, will develop this plan.

(b) This plan will cover improved fuel economy and the use of synthetic liquid fuels derived from coal, shale, and tar sands.

(3) Priority Group III is energy technology demonstration with DOE support.

(a) Our objective for this priority group is to identify, evaluate, and pursue joint energy initiatives with the Department of Energy which will help us:

(1) To reduce our energy consumption and dependency on foreign sources of oil, and

(2) Accelerate the development and early commercialization of new energy technologies. We can do this through the experience we gain in the construction, operation, and maintenance of new systems. This will enable manufacturers to get on the learning curve through early DOD buys.

(b) Our initiatives include:

(1) Oil shale test program;

(2) Solar federal buildings programs;

(3) Photovoltaics--you are all familiar with Don Faehn's work at MERADCOM, I'm sure;

(4) Geothermal electric plant (China Lake, CA);

(5) Geothermal space heating (Hill AFB, Utah);

(6) Wood burning heating plant (Ft. Stewart, GA); and,

(7) Showcases of energy technology at:

(a) McClellan AFB, California,

(b) Army Lone Star Ammunition Plant, Texas, and

(c) Sewells Point Naval Complex, Virginia.

(4) Priority Group IV is designed to optimize energy use through energy conservation programs such as:

(a) Energy conservation investment program, and

(b) Energy conservation and management.

VII. ENERGY TECHNOLOGY APPLICATION

Our program effort to use advanced energy technology in military applications covers both mobility and facilities energy.

(1) Mobility Energy

(a) Aircraft--ceramic turbine blades,

(b) Ships--hull coating, and

(c) Ground systems such as advanced mobile electric power generators.

(2) Facilities

(a) Conservation technologies--relamping, and

(b) Energy conversion technologies--refuse derived fuel.

The lead service responsibilities for key energy technologies I spoke of earlier will greatly help us achieve our energy goals and objectives. We have assigned the:

(3) Army

(a) Photovoltaic energy systems,

(b) Multifuel aircraft propulsion systems (excludes fixed wing or ship),

(c) Wood-fired boilers,

(d) Energy conserving structures and construction technology,

(e) Solar heating and cooling,

(f) Advanced low head hydropower,

(g) Computer programs to determine energy characteristics of buildings,

(h) Nuclear power for landbased applications, and

(i) Electric vehicles.

(4) Navy has responsibility for:

(a) Geothermal energy,

(b) Co-generation,

(c) Energy monitoring and control systems,

(d) Refuse derived fuel, and

(e) Ship propulsion systems.

(5) The Air Force is assigned:

(a) Wind energy,

(b) Fixed wing aircraft propulsion systems,

(c) Colloidal boiler fuels,

(d) Fuel cells,

(e) Advanced technologies to burn coal, and

(f) Energy storage for mobile systems.

VIII. CONCLUSION

In summary, our energy management program covers:

(1) Energy supply to ensure energy requirements to support mobility operations and our installations,

(2) Energy conservation to reduce energy consumption in mobility fuels and utility energy sources that support our installations, and

(3) Energy technology applications to better use depletable energy resources and to demonstrate the feasibility of new energy technologies.

The challenge of the Defense energy management program in the:

(1) Near- and midterm is to assure adequate fuel through supply and conservation initiatives, and for the

(2) Longer term, will be to avail ourselves of more secure, plentiful energy resources through technological advances.

I am confident that with the continued support of industry, such as The BDM Corporation and the Department of Energy, the Department of Defense will continue to be a leader in the pursuit of national energy goals.

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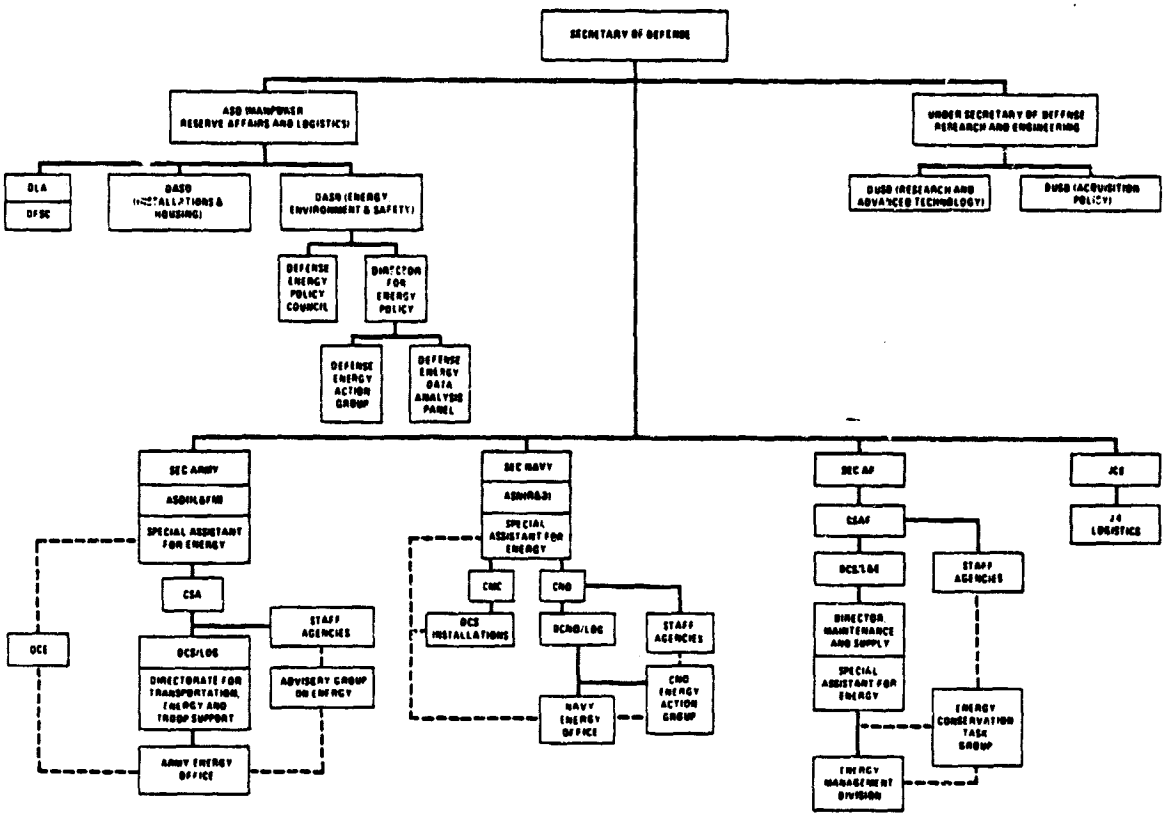
Energy Program

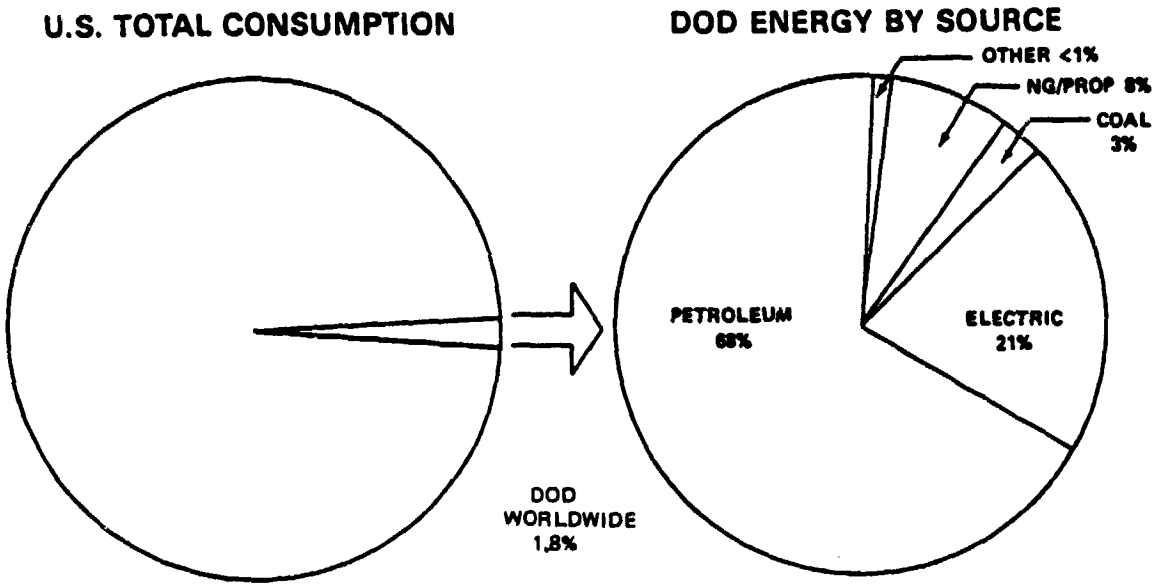
OVERVIEW

- MANAGEMENT
- ENERGY CONSUMPTION
- GOALS AND OBJECTIVES
- ENERGY PRIORITIES
- DOD/DOE INITIATIVES

DEPARTMENT OF DEFENSE ENERGY MANAGEMENT



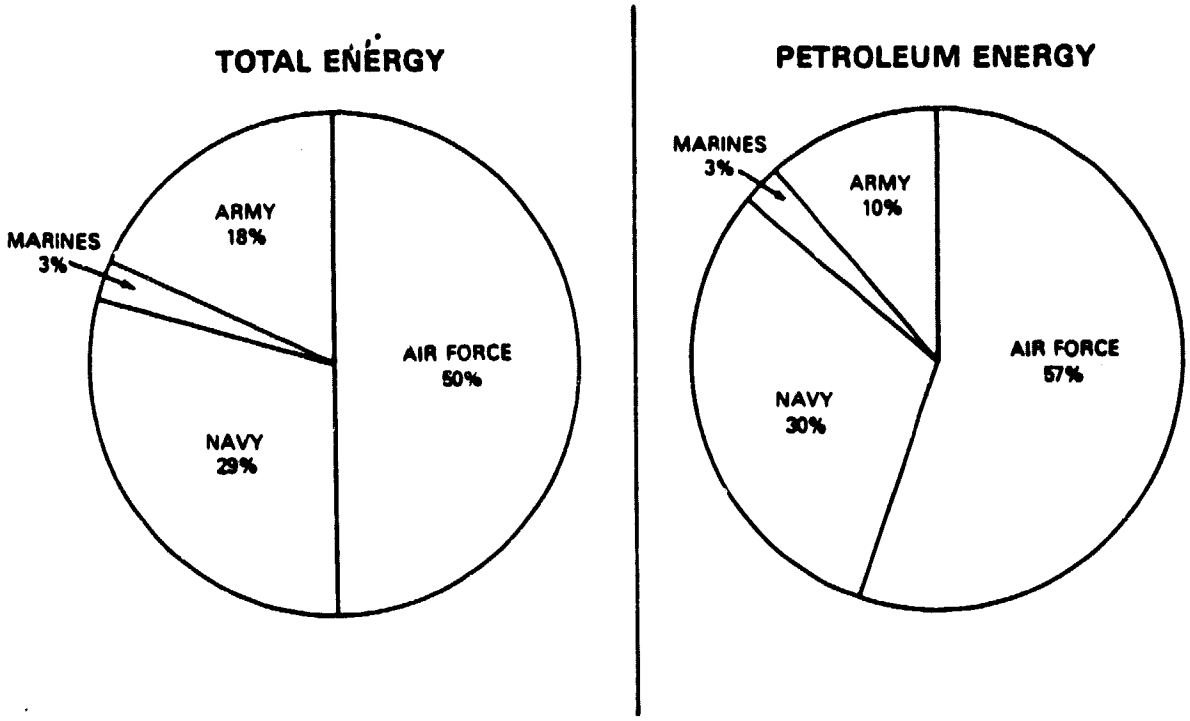
ENERGY CONSUMPTION
FY 1978



13,901 MILLION BARRELS
OF OIL EQUIVALENT (ESTIMATE)

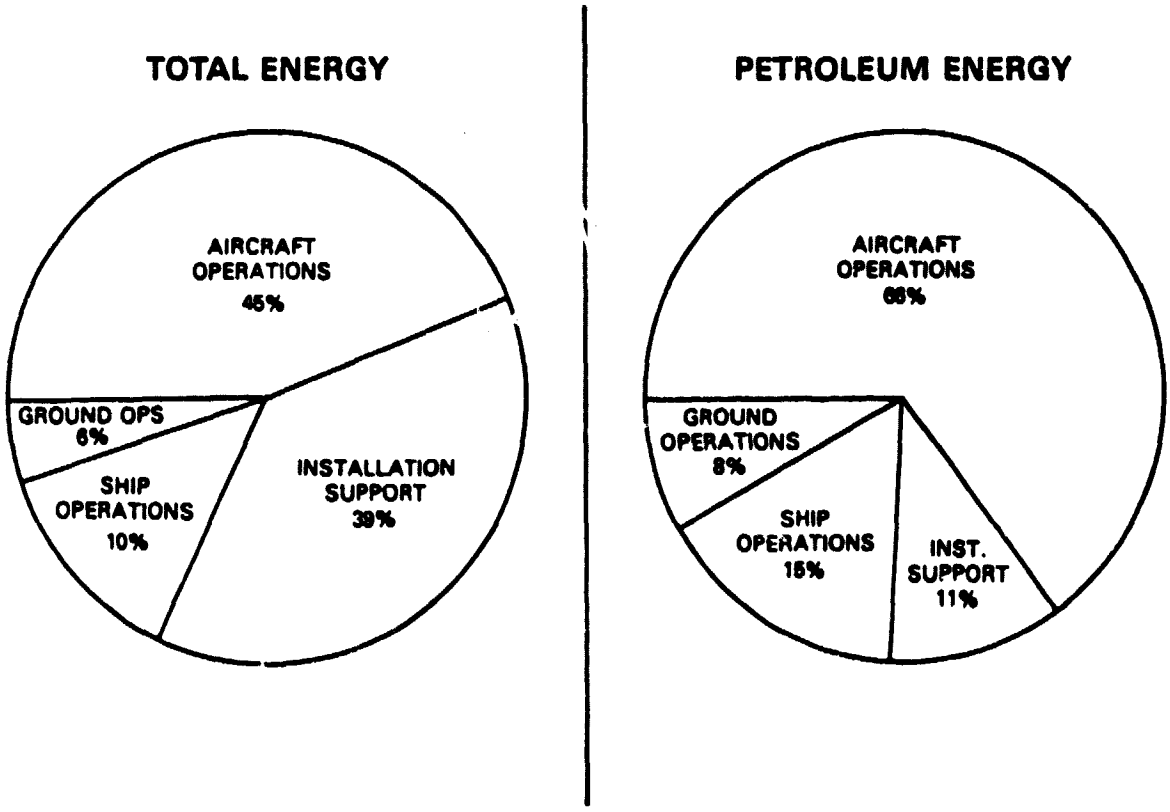
252 MILLION BARRELS
OF OIL EQUIVALENT

DoD ENERGY DEMAND
(By Military Service)
FY 1978



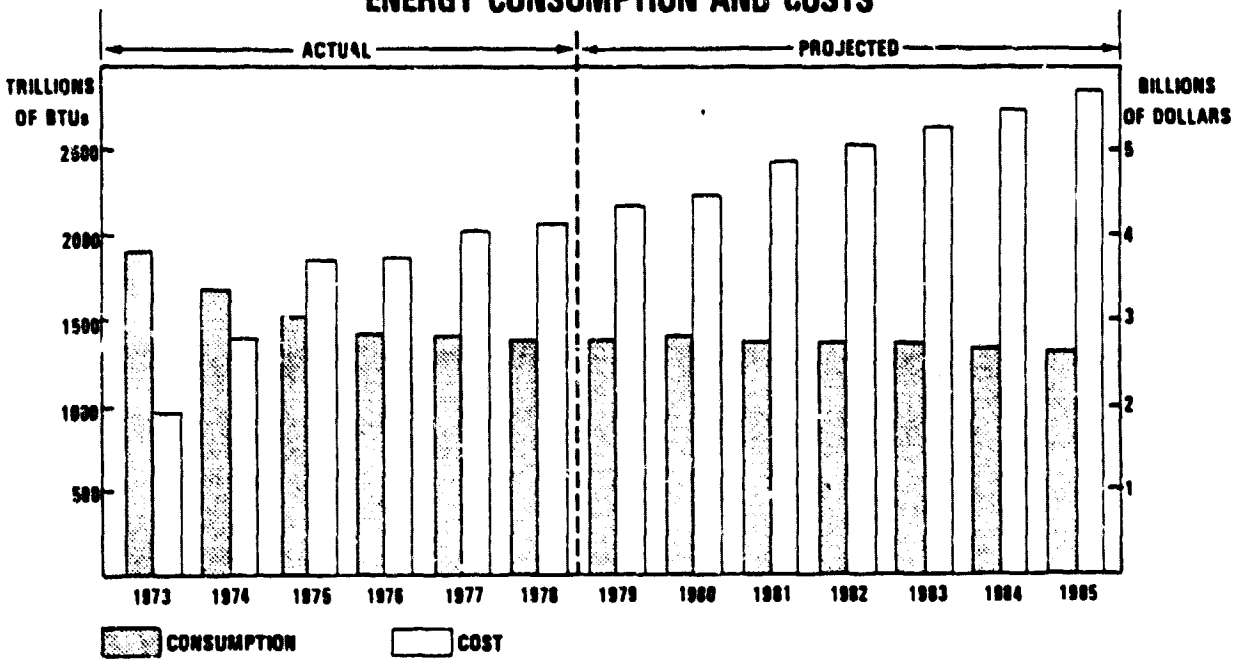
SOURCE: DEFENSE ENERGY INFORMATION SYSTEM

DoD ENERGY CONSUMPTION
(By Operational Function)
FY 1978



SOURCE: DEFENSE ENERGY INFORMATION SYSTEM

DEPARTMENT OF DEFENSE
ENERGY CONSUMPTION AND COSTS



DEFENSE ENERGY MANAGEMENT

GOALS AND OBJECTIVES

ENERGY TECHNOLOGY APPLICATION

- MOBILITY ENERGY
- FACILITIES
- LEAD SERVICE RESPONSIBILITIES

- DOD CONSERVATION GOALS:
  - REDUCE ENERGY IN EXISTING BUILDINGS:
    - 12% VIA ECIP
    - 8% VIA OTHER INITIATIVES
  - METER AND AUDIT BUILDINGS PER DOE GUIDELINES
  - DEVELOP AND DISTRIBUTE TO EACH INSTALLATION A LIST OF ENERGY CONSERVATION MEASURES
  - LIMIT OPERATIONAL ENERGY CONSUMPTION BY TRAINING, TACTICAL AND STRATEGIC FORCES IN 1985 TO THE 1975 LEVEL. DO THIS WITH:
    - MORE EFFICIENT PROPULSION SYSTEMS
    - MORE EFFICIENT USE OF EQUIPMENT
    - GREATER USE OF SIMULATORS

SUPPLY

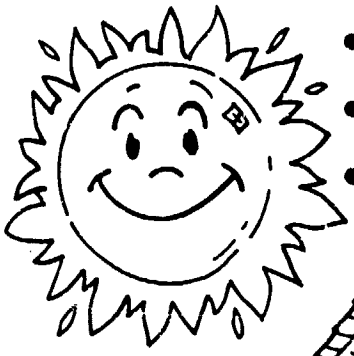
- INSTALLATION ENERGY SUPPLY GOALS:
  - OBTAIN 10% OF ENERGY BY 1985 FROM:
    - SOLID FUELS
  - OBTAIN 1% OF DOD INSTALLATION ENERGY BY 1985 FROM:
    - SOLAR AND GEOTHERMAL
- MOBILITY ENERGY SUPPLY GOALS:
  - DEVISE, WITH DOE, A STRATEGY TO MINIMIZE DISRUPTION OF FUEL SUPPLY TO DOD
  - DO R&D ON PROPULSION SYSTEMS AND FUEL TO SPECIFICATIONS RANGE OF FUELS WE CAN USE
  - PLAN AGAINST THE CONTINGENCY OF A FUTURE TRANSITION FROM PETROLEUM TO SYNFUELS

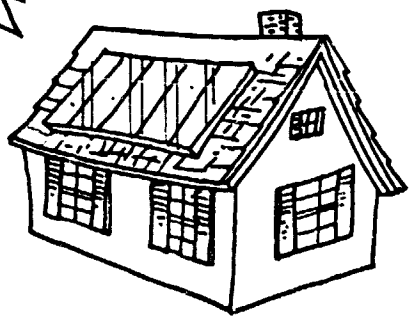
DEFENSE ENERGY PRIORITIES 1979

- FUEL AVAILABILITY
- ENERGY R&D PLAN
- DoD/DoE INITIATIVES
- OPTIMIZE UTILITY BILLS

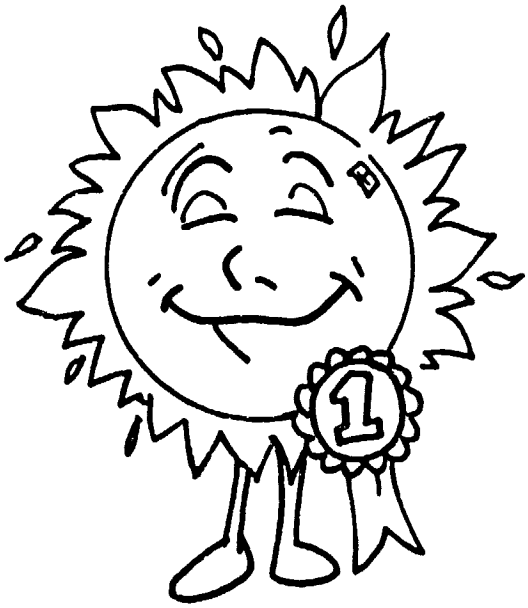
ENERGY TECHNOLOGY DEMONSTRATION PROJECTS

- OIL SHALE
- SOLAR HEATING & COOLING
- PHOTOVOLTAICS
- WOOD-FIRED BOILERS
- GEOTHERMAL ELECTRIC & HEATING
- "SHOWCASE" INSTALLATIONS





WE'RE NO. 1



BUT TRYING HARDER

The following questions were directed to and answered by Mr. George Marienthal:

Q. "Do points of contact exist to aid the transfer of information and ideas between the various branches of the armed services concerning this project (Showcase)?"

A. "Yes. This keeps any one branch from closing its doors and operating in a vacuum."

Q. "Does 'the outside' have access to these points of contact within the services?"

A. "Absolutely. The energy program should operate 'in the sunshine'."

Q. "The on-site base locations mentioned are within the United States. Seeing that there are considerable foreign bases of the same size and nature, are there any comparable projects for these installations?"

A. "There are things being done overseas, but obviously not to the same extent as here in the States. This is due to the fact that here we are dealing with the importation of petroleum from foreign sources. Hopefully, these programs will help reduce this dependence. Hence, domestic projects have priority."

Q. "Concerning fuel replacement in particular, could petroleum dependence in areas like Diego Garcia be reduced or ended?"

A. "Conversion possibilities are being explored in these types of areas since they are dependent on many different types of fuel."

Q. "It was mentioned that the Army is involved in solar heating and cooling. Is there a point of contact for inquires?"

A. "Yes. Don Faehn is the point of contact at Fort Belvoir for photovoltaics."

Q. "During the course of this workshop we will be looking at potential military applications for this technology in several different versions. In particular, we will be examining potential mobile or portable applications, isolated applications, and facilities applications. If it is determined that indeed there are feasible mission related military applications for this technology, given that there is not now a lead service or energy technology demonstration project, what would be the proper routes to take to turn these understandings into action programs?"

A. "This quest would involve a normal marketing problem to the military which is a tough endeavor. There is no well-defined nor straightforward method that can be recited to get the job done. Generally, one must have good support from users of the technology, must get inside the military lab structures and R&D programs, and must find support from within the Pentagon."

Q. "Then can it be assumed that since we have representatives from the laboratories, from the users, from the manufacturers, and from the civil sector as well, that this, a first step to setting the clockwork in motion, and that positive action will need the continued support and effort of all those involved?"

A. "Quite certainly."

Q. "As is known, one of the goals of this conference is to implement this sort of thing (methods of marketing to military). A year and a half ago your office took a very strong position in this line to forward this specific technology of solar thermal electric power in a pamphlet which was sent to DOD R&E. This was met with rather apparent apathy. Has the atmosphere changed any since this time, or is there a better responsiveness now? What happens from below obviously is a reaction of the interest from above. How can implementation take place if the leaders of the R&D community will not come forward?"

A. "In all honesty, things are [illegible] better now. Military R&D managers are currently interested in the F-18, the MX's, etc., as is desired. On the other hand, it is tough to get less than top persons interested in the sort of things we are pushing. We are trying; unfortunately the situation is not inspiring."

Q. "What are the base locations of Showcase?"

A. "The Red River Army Depot is the Army Showcase base location. The Navy's Showcase is at Norfolk, VA, and the Air Force has their showcase at the McClellan base, Sacramento, CA. These bases, especially Norfolk and Sacramento, have high military and civil visibility which should greatly enhance the programs."

Q. "Persons who represent industry are hearing quite inspiring and impressive goals from DOD and DOE; however, it is quite difficult to see any affirmative action towards meeting those stated goals. It is also difficult to understand the rationale used for selecting photovoltaics and geothermal technology over others such as solar thermal. Here we are talking about Brayton technology, yet the Army is probably the only manufacturer of Brayton engines, and their program has little in common with what we are trying to do here. Hence, as a representative of industry, I would like to encourage the tying together of, and more

specific action toward the ideas, goals, and technologies because they are worthy of merit. Finally, as a stated question, what is the specific role and impact of DOD R&E in this?"

A. "In iteration of my earlier response to this question, DOD R&E is involved, yet not to the degree desirable. Although they are responsible, they have not measured up to this reponsibility. In response to the question concerning action, I have that responsibility by default. I am, therefore, pushing this effort which otherwise would not get pushed. Within the Department of Defense, the program is tied together quite clearly with its structure, goals, and directions well mapped into 1985. I extend appologies for not being able to display this in a more explicit manner. The input of these goals on other segments of society, including industry, is unclear. DOD makes its own goals at the direction of the Commander-in-Chief. Whether or not we are to provide leadership to industry, I don't know. DOD and DOE spent a year agonizing over various technologies to concentrate on. We concentrated on those technologies which were between now and 'way down the road,' and which could be implemented in some of our 400 odd cities. From this process, geothermal and solar electric technologies emerged."

Q. "Given the annual budget considerations that the Department of Defense has to work with, do the higher front end costs associated with solar technology inhibit lower level personnel from proposing solar projects? Likewise, do these same costs keep higher level personnel from going to Congress with what appear to be inflated budget reports?"

A. "In both cases, this is correct. The life cycle cost effectiveness figures associated with solar technology inhibit interest when money is scarce."

Comment "It appears that a portable fuel source is what is needed and that other topics are peripheral. Your program seems to lack an aggressive effort with synthetic fuels. Perhaps the high temperature point focusing solar technology could add a new dimension to the production of synthetic fuels. One would think that the Defense Department is uniquely capable of such an endeavor."

Q. "During the presentation, one slide displayed that 39 percent of the total energy DOD uses goes to facilities. Systems that are being discussed here are capable of displacing a large fraction of that 39 percent. Conceptually, if X amount of fuel is displaced from facility operations, that X amount can be used to help offset fuel demands for aircraft and logistical operations. Is the same true in actual practice? If indeed the technologies being considered here can offset DOD's petroleum use by 10, 20, or 30 percent, is this impact to those concerned enough to cause active support of such technology, or is this simply too abstract?"

A. "Certainly the ideas are correct; however, petroleum represents only 11 percent of the total energy figure. If indeed petroleum use could be reduced at facilities, mobile operations could receive the displaced allotment."

Q. "Cooperation has been encouraged between DOD labs and other national labs. Have roles been defined for DOD vis-a-vis other national labs?"

A. "No. These roles have not been defined satisfactorily."

Q. "Will you be taking over management of the shale oil program, or will that be conducted by R&D?"

A. "Hopefully that will be handled by Research and Engineering. The Department of Energy will be responsible for the management of production and refinement of shale. Then the Department of Defense will be responsible for the specifications on the fuel."

SMALL RENEWABLE ENERGY SYSTEMS AND THE PURSUIT OF INDEPENDENCE

Martin R. Adams
Deputy Program Director
for Solar, Geothermal, Electric
and Storage Systems
Department of Energy

Mr. Marienthal, Mr. Chairman, workshop participants...I am particularly pleased to be here this morning, for I have been convinced for some time that we must, as a nation, place a great deal of emphasis on SMALL, marketable, renewable energy systems if we are to retain our accustomed independence at the family, community and small industrial levels -- and I feel that you will also conclude in this workshop that such systems have a vital role to play in many military applications.

Perhaps you have heard of the ancient Chinese curse, "May you live in interesting times." For those of us in the energy business, 1979 has not been boring. Public interest and concern over the national energy picture is at its highest level since the 1973 embargo. Over the past five to six years we've had almost a continual shortfall in one fuel or another -- but the gasoline shortage this summer really hit us where it hurts; in our personal independence. For the first time, we as individuals, have more directly felt the energy constraints that some businesses and communities have encountered earlier, and have had to stop and plan real changes in our lives. Sometimes it was relatively insignificant, like planning the family schedule around whose car is odd or even, or taking a bus to work. On the other hand, a family which was considering buying a house fifty miles from their place of work may have had to resort to second thoughts. At the moment we have plenty of gasoline, but we know that it will never be 40 cents a gallon again.

When this country was founded we were promised life, liberty and the pursuit of happiness. Somehow we've come to equate these values with the right to cheap, abundant energy from depletable fuels. We tend to forget that many of our forebearers ran their lives on whatever the individual family or small community was able to gather in and that most of their fuel sources were renewable. Until the coming of a nationwide rail network made it possible to distribute coal to every home, the colonial family and the Western homesteader lived pretty much the same. Homes were heated with wood fires. Land transportation and agriculture ran on horses, mules, oxen, and people. Wind moved boats on river and ocean. Lighting came from bear fat or whale oil or beeswax or sheep tallow. Water power ground wheat into flour and spun wool and cotton into yarn for clothes. When we went to war, we used horses and mules to haul artillery and wind and galley slaves at sea. This first age of "Small Renewable Energy Systems" lasted a remarkably long time and never died out in the more remote parts of the United States. Henry Ford was a long-time advocate of alcohol from farm crops as a motor fuel, reasoning that this would take up the slack in wheat production as horses were phased out. West Virginia coal was shipped to Washington on mule barges via the C&O Canal until 1924. Windmills supplied electric power and irrigation pumping on farms until the 30's, when they were replaced by rural electrification programs. Boise, Idaho, began heating homes with geothermal energy in the 1890's; this system is still functioning, although many homes went "modern" with natural gas later on. Solar hot water heaters were popular in Florida before cheap depletable fuels came along.

Perhaps by coincidence, the discovery of large quantities of oil and gas in this country occurred during the heyday of the giant trusts. A consumption economy made a lot of sense at the time -- the consumer enjoyed a warmer home and the ability to get around fast, and the industries profited. During this period the United States was transformed into a world power, partly on the oasis of our large domestic energy resources and complex distribution systems. We rationed gasoline during the Second World War, but we didn't have to fight out the consequences of an embargo to win

the war. Even as we started importing cheap Middle Eastern crude to take care of more and more of our needs, we became smug about our energy future. The Sherman Anti-Trust Act and the progressive income tax diminished the power of individual energy resource companies, but the age of conspicuous consumption went on and on.

Meanwhile, individual Americans became accustomed to energy that was not only cheap but convenient. No need to go out and feed and water and curry Old Paint every morning -- just drive him around the corner and fill him up every couple of days. Chopping wood is something you do to add a little atmosphere to the parlour. A flick of the switch turns night into day and winter into summer and summer into winter. Don't waste valuable personal energy on striking matches, brushing teeth, or opening cans: an electric appliance for every task. Even now, the most popular wedding present in D.C. is a machine that performs a dozen tasks that used to be done with a paring knife or a hand-operated egg beater. Need to get away from it all? If you don't have a camper, you can still load up the family car or hop on a plane and head for the beach or the hills.

The price we've paid for all this convenience is the loss of our independence, of control over our lives. Indeed, we are dependent upon access to the oil resources of the Middle East, a politically volatile region in the shadow of the Soviet Union. The military implications of our vulnerability are becoming more clear daily. The possibility of Soviet control of the Middle East oil tap can no longer be ignored.

This presents a particularly difficult energy problem to our military. To be a deterrent, we must be prepared to defend the Middle East and Persian Gulf and the sea lanes without having access to fuels from these areas. Energy independence of our military forces is now a requirement if they are to be a deterrent. In addition, because of the quantity of energy resources used by the military, conversion to alternate fuel sources, [illegible] possible, becomes an important factor in meeting the nation's energy [illegible] Many such opportunities lie in the SMALL solar applications category.

I understand that the Department of Defense will convert 19 percent of their energy needs to more abundant solid fuels by 1985 and 1 percent to solar or renewable sources.

These are important goals, for the goal for solar (and other renewables) amount to 50MW in 1985.

The Department of Energy is assisting industry in developing large central energy conversion systems in solar thermal, photovoltaics, ocean thermal and geothermal areas. These involve electric power production systems up to 100 megawatts and more. They are also targeted for large process heat and large fuels and chemical production. In their respective areas of application, they all have national importance.

But the renewable energy activities that are exciting to me are the small, individually operated, system applications. Among others, we now have a solar thermal system pumping irrigation water in New Mexico; a small photovoltaic system providing electric power to an Indian village in Schucholi, Arizona, and a 200 KW wind turbine in operation at Culebra, Puerto Rico.

In keeping with this, this workshop is devoted to solar thermal electric power applications ranging from a few megawatts down to 15 kilowatts in size. More particularly, it involves parabolic dish (or point focusing) technology, one of our most promising concepts for small community, small industrial and military applications. The importance of this technology stems from its high potential efficiency, and from its characteristic modularity. These characteristics make it a "high performer", one that is easily mass produced and that has a minimum in field installation costs. JPL is technically managing this program for DOE and is doing a fine job.

Most of you are also aware of the cooperative DOE/DOD activity in developing a 100 KW experiment for the U.S. Navy Civil Engineering Laboratory that JPL is also managing as part of our solar thermal applications activity. It is an exciting project and is an important step in the dish technology program. But you will hear more about this during the workshop.

For now I'd like to sum up. I am convinced that we must place a great deal of emphasis on SMALL renewable energy systems if we are to retain our

independence as individuals, and on a community and small industrial basis. As a Nation, we have the resources to do this job -- and are well underway. This workshop is an integral step in this process and I wish you much success in meeting your objective over the next few days.

The following questions were directed to and answered by Mr. Martin Adams, DOE:

Q. "Is DOE prepared to take on OMB concerning the discount rate?"

A. "DOE is prepared; however, I would not hazard a guess over the outcome."

Q. "Assuming that these systems can achieve a cost of $5.00 per million BTU, a problem still exists because of the tax gradient between a capital item and an expense of fuel. The National Energy Act attempted to warp that a bit and the IRS took exception. Is anything being done to put a damper on this burden and increase the incentive?"

A. "We have had analysts review several incentive packages in light of this problem. The results were recorded in several papers which I could furnish. One paper had the surprising results that if the provisions offered in the NEA were 20% (ITC), then the depletable and nondepletable technologies were about at a parity. Note that this was only one analyst who came to this conclusion. However, DOE will continue to have incentives improved due to the high capital intensity."

Q. "Is there a directory which contains the breakdown of persons within DOE who are working on various projects and if so, is it available for distribution so that these persons may be contacted?"

A. "Yes. It can be obtained by requesting the Gold Book which is publicly available."

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Q. "Again representing the manufacturing sector, I would like to add that from a preliminary standpoint it appears that two to three times the current budget amount will be needed to even begin to accomplish your stated goals. This is in addition to the R&D. When the goals presented by Mr. Marienthal are imposed on top of these, there is even more work to be done. These five year plans just are not viable."

A. "Your comments and concern are appreciated. We are concerned also."

Q. "The Department of Energy is often using the Federal Grant and Cooperative Agreement Act of 1977 on a variety of programs where it is intended that the ultimate industry supposedly will benefit. It also appears that the Act might be used in some cases where the benefit is doubtful or the risk is high. Do you anticipate using this Act for the type of technology discussed here?"

A. "As of now we have not developed our strategy of the program for small scale systems. This is one area that will require close attention, so we will be looking at this closely."

APPLICATIONS OVERVIEW

MILITARY APPLICATIONS FOR ELECTRIC POWER SYSTEMS - AN OVERVIEW

J. Scott Hauger
Program Manager, Military Energy Programs
The BDM Corporation

In conjunction with the workshop, The BDM Corporation conducted a study for the Jet Propulsion Laboratory to define plant requirements, markets, and cost goals for military applications for point focusing solar thermal electric technologies. This study served as BDM's integrative presentation at the workshop.

The BDM study determined that the Army, Navy, Air Force and Marine Corps currently maintain an inventory of approximately 1800 MW with an annual procurement potential of 140 MW for power systems 15 KW and larger. The plant requirements of all these systems can potentially be met by advanced heat engines of the types under development for PFDR application. Solar provided heat is consistent with approximately 33 MW annual procurement. An additional 30 MW per year could be used if DOD seeks self sufficiency of mission critical facilities.

Total military power purchased from utilities is the equivalent of approximately 5000 MW generating capacity. If Congress were to authorize the capital expense for total base self-sufficiency, an additional 220 MW annual market would result. Cogenerating systems would increase the demand. Current service goals may be presented by the Air Force, which has the objective of meeting 25 percent of facilities power by renewable resources and 25 percent with alternate fuels in the year 2000.

Cost goals vary with assumptions, but a baseline case assuming 8 percent fuel escalation indicates cost goals of 120-210 mills/KWh, depending on size, for military generators and 86 mills/KWh for purchased electricity. This indicates a concentrator receiver installed cost goal of $2,500 to $2,700 for average insolation areas.

SUMMARY OF RESULTS I

- ARMY, NAVY, AND AIR FORCE POWER REQUIREMENTS TACTICAL, THEATER, REMOTE, AND EMERGENCY/ BACK-UP POWER TOTAL 1600 MW
- THE ANNUAL PROCUREMENT POTENTIAL FOR ELECTRIC POWER SYSTEMS IS 140 MW
- THE PLANT REQUIREMENTS OF ALL OF THESE SYSTEMS CAN POTENTIALLY BE SATISFIED BY STIRLING OR BRAYTON CYCLE THERMAL ELECTRIC POWER SYSTEMS
- SOLAR PROVIDED HEAT IS CONSISTENT WITH THE PLANT REQUIREMENTS OF APPROXIMATELY 23 PERCENT OF ANNUAL PROCUREMENT, OR 33 MW. A FURTHER 30 MW/YEAR IS POTENTIALLY FEASIBLE IF SELF SUFFICIENCY OF CRITICAL MILITARY POWER SOURCES IS FUNDED BY CONGRESS.

3138, 79W

SUMMARY OF RESULTS II

- IF TOTAL BASE SELF SUFFICIENCY WERE DESIRED, PLANT REQUIREMENTS ARE CONSISTENT WITH AN ADDITIONAL 220 MW ANNUAL PROCUREMENT.
- COST GOALS VARY WITH ASSUMPTIONS, AND ARE MOST SENSITIVE TO ESCALATING FUEL COSTS. A BASE LINE SCENARIO INDICATES SYSTEM GOALS OF 120-210 MILLS/KWH FOR MOST MILITARY APPLICATIONS ~ 86 MILLS/KWH FOR FACILITIES APPLICATIONS.
- THE BENEFIT OF SOLAR PROVIDED HEAT SHOULD BE TESTED AGAINST THE LOWER COST OF POWER FROM COMBUSTION IN THERMAL ELECTRIC SYSTEMS, BECAUSE THEIR DEVELOPMENT IS IMPLIED BY A SUCCESSFUL STEP TECHNOLOGY STEP DEVELOPMENT.
- A BASELINE SCENARIO INDICATES ARRAY/RECEIVER COST GOALS OF $900-$2700/KW DEPENDING ON DUTY CYCLE.

MILITARY POWER APPLICATION CATEGORIES-I

- TACTICAL SYSTEMS
  - MOBILE ELECTRIC POWER — TYPICALLY DIVISION LEVEL AND BELOW
  - ASSIGNED TO TROOP UNITS — 0.5 TO 750 KW
- THEATER SYSTEMS
  - TRANSPORTABLE PRIME POWER — "TEMPORARY FACILITIES"
  - ASSIGNED TO ENGINEER UNITS — $\geq$ 750 KW
- ISOLATED/REMOTE SYSTEMS
  - PERMANENT INSTALLATIONS WHICH GENERATE THEIR OWN POWER
  - TYPICALLY SMALL (15-1000 KW) AND GEOGRAPHICALLY ISOLATED

MILITARY POWER APPLICATION CATEGORIES II

- EMERGENCY/STANDBY SYSTEMS
  - FIXED OR PORTABLE POWER SYSTEMS WHICH FUNCTION WHEN PRIME POWER FAILS

- FACILITIES AND PERMANENT INSTALLATIONS
  - THOSE WHICH PURCHASE POWER FROM COMMERCIAL UTILITIES
  - TYPICALLY LARGE > 1000 KW EQUIVALENT.

OPERATIONAL REQUIREMENTS OVERVIEW

	TACTICAL	THEATER	REMOTE	EMERGENCY	FACILITY
SIZE/WEIGHT	●	●			
EMISSIONS (NOISE, IR, VISIBLE)	●				
FUEL TYPE	●				●
HARDNESS	●				
DUTY CYCLE				●	
START TIME	●			●	
RAM*	●	●	●		
FUEL SUPPLY		●	●		
COSTS			●	●	●

*RELIABILITY, AVAILABILITY, MAINTAINABILITY

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TACTICAL APPLICATIONS

CRITICAL REQUIREMENTS

SIZE:	~ 2.5 FT^3/KW 0.9-1.5 FT^3/KW	RANGE:	0.6-7.1 FT^3/KW	CURRENT SYSTEMS QMR
WEIGHT:	~ 50 LBS/KW 18-25 LBS/KW		16-186 LBS/KW	CURRENT SYSTEMS QMR
EMISSIONS:				
NOISE	NON DETECTABLE AT 100 METERS			MERADCOM
IR	NO STANDARD. MINIMUM POSSIBLE EXHAUST			--
VISIBLE	CAMOUFLAGEABLE			--
HARDNESS	OPERATE AFTER 12 INCH DROP AND 45 MINUTE VIBRATION AT 7-500 CPS.			CURRENT SYSTEMS
START TIME:	15 MINUTES, ALL WEATHER			CURRENT SYSTEMS
RAM:	RELIABILITY:	95% OVER 24 HOURS		QMR
	AVAILABILITY:	97% COMBAT READY		QMR
	MAINTAINABILITY:	600 HOURS MTBO		QMR
		250 HOURS SCHEDULED MAINTENANCE		QMR
	MAINTENANCE			
FUEL TYPE:	MULTI-FUEL			MERADCOM

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TACTICAL APPLICATIONS

OTHER REQUIREMENTS

DUTY CYCLE:	VARIES GREATLY FOR COMBAT, TRAINING, GARRISON, RESERVE
FUEL SUPPLY:	MINIMUM POSSIBLE ESPECIALLY FOR MAN-PACKED SYSTEMS. FUEL CONSUMPTION 2.8 lbs/kWh BY QMR (GAS TURBINE) CURRENT SYSTEMS 1.3 lbs/kWh (DIESEL)
COSTS:	CAN BE TRADED OFF FOR INCREASED MISSION EFFECTIVENESS

3028/79W

THEATER APPLICATIONS

CRITICAL REQUIREMENTS

SIZE	2.3-6 FT^3/KW	CURRENT SYSTEMS
WEIGHT	58-130 LBS/KW	CURRENT SYSTEMS
RAM	10,000 HRS MTBO HIGH AVAILABILITY (UNQUALIFIED) LOW MAINTENANCE (UNQUALIFIED)	FESA
FUEL SUPPLY	750 KW CONSUMES 1500 GAL/DAY (.084 GAL/KWH) 4500 KW CONSUMES 8000 GAL/DAY (.075 GAL/KWH) THUS STORAGE AND SUPPLY ARE A PROBLEM	CURRENT SYSTEMS

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THEATER APPLICATIONS
OTHER REQUIREMENTS

EMISSIONS:	SAFETY AND ENVIRONMENTAL REQUIREMENTS PREVAIL
FUEL TYPE:	MULTI-FUEL A PLUS, NOT REQUIRED
HARDNESS:	CURRENT SYSTEMS ARE VAN MOUNTED AND NORMALLY RUN WITHIN A SECURITY FENCE
DUTY CYCLE:	24 HOURS/DAY DURING DEPLOYMENT 20-35 PERCENT DEPLOYED IN PEACETIME
START TIME:	NOT CRITICAL
COSTS:	FUEL COST IS A DRIVER FOR CURRENT SYSTEMS

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REMOTE APPLICATIONS

CRITICAL REQUIREMENTS

RAM:	53 MINUTES UNSCHEDULED DOWN—TIME/ YEAR (ACOM)
	OFTEN TWO BACK-UP SYSTEMS (USAF)
FUEL SUPPLY:	AVAILABILITY VARIES, BUT DELIVERIES ARE OFTEN EXPENSIVE TO MAKE
COSTS:	RELIABILITY REQUIREMENTS DRIVE CURRENT CAPITAL COSTS AS HIGH AS $1400/kW. COST OF FUEL DELIVERY IS IMPOSSIBLE TO GENERALIZE, BUT OFTEN VERY HIGH

REMOTE APPLICATIONS

OTHER REQUIREMENTS

SIZE/WEIGHT: NOT A CRUCIAL FACTOR

EMISSIONS: SAFETY AND ENVIRONMENTAL STANDARDS PREDOMINATE

FUEL TYPE: NOT CRITICAL. IN SOME LOCATIONS, LOCALLY AVAILABLE FUEL CAPABILITY WOULD BE USEFUL

HARDNESS: ARCTIC AND DESERT LOCATIONS HAVE HARSH ENVIRONMENT

DUTY CYCLE: VARIES, USUALLY CONTINUOUS, SOMETIMES WITH PEAKS DUE TO OPERATIONAL STIMULUS

START TIME: N/A

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EMERGENCY/BACK-UP APPLICATIONS

CRITICAL REQUIREMENTS

DUTY CYCLE:	TEST ONCE PER WEEK PLUS SPORADIC, USUALLY SHORT OPERATIONS
START TIME:	IMMEDIATE RESPONSE REQUIRED
COSTS:	FIRST COST PREDOMINATES, A FULL DUPLICATE CAPACITY FOR CRITICAL REQUIREMENTS

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FACILITY APPLICATIONS

CRITICAL REQUIREMENTS

COSTS: BECAUSE ALL U.S. MILITARY INSTALLATIONS, EXCEPT REMOTE, PURCHASE POWER, COST IS DRIVING FACTOR. DEPENDS ON CONGRESSIONAL APPROPRIATION

MILITARY FACILITIES REQUIREMENTS RESEMBLE SMALL COMMUNITIES IN GENERAL

FUEL TYPE: A MULTI-FUEL CAPACITY WOULD ALLOW ADVANTAGE TO BE TAKEN OF LOWEST COST/BTU OVER TIME

3039/79W

GENERAL COSTING ASSUMPTIONS

BASELINE ECONOMIC ASSUMPTIONS

- 11% DISCOUNT RATE
- 10% INFLATION RATE
- 8% DIESEL FUEL ESCALATION RATE

SUBSYSTEM COST ASSUMPTIONS

- HEAT ENGINES
  - $230/KW INITIAL COST
  - 5% ANNUAL O&M COST
- STORAGE
  - REDOX BATTERY $150/KW + $7/KWH OF STORAGE
  - HIGH TEMP. THERMAL $40/KW + $31/KWH OF STORAGE
  - LEAD-ACID BATTERY: $40/KWH
  - ALL 1% ANNUAL O&M COST
  - $\eta_B = .75$, $\eta_T = .91$
- COLLECTORS
  - 2% ANNUAL O&M COST

COST METHODOLOGY I

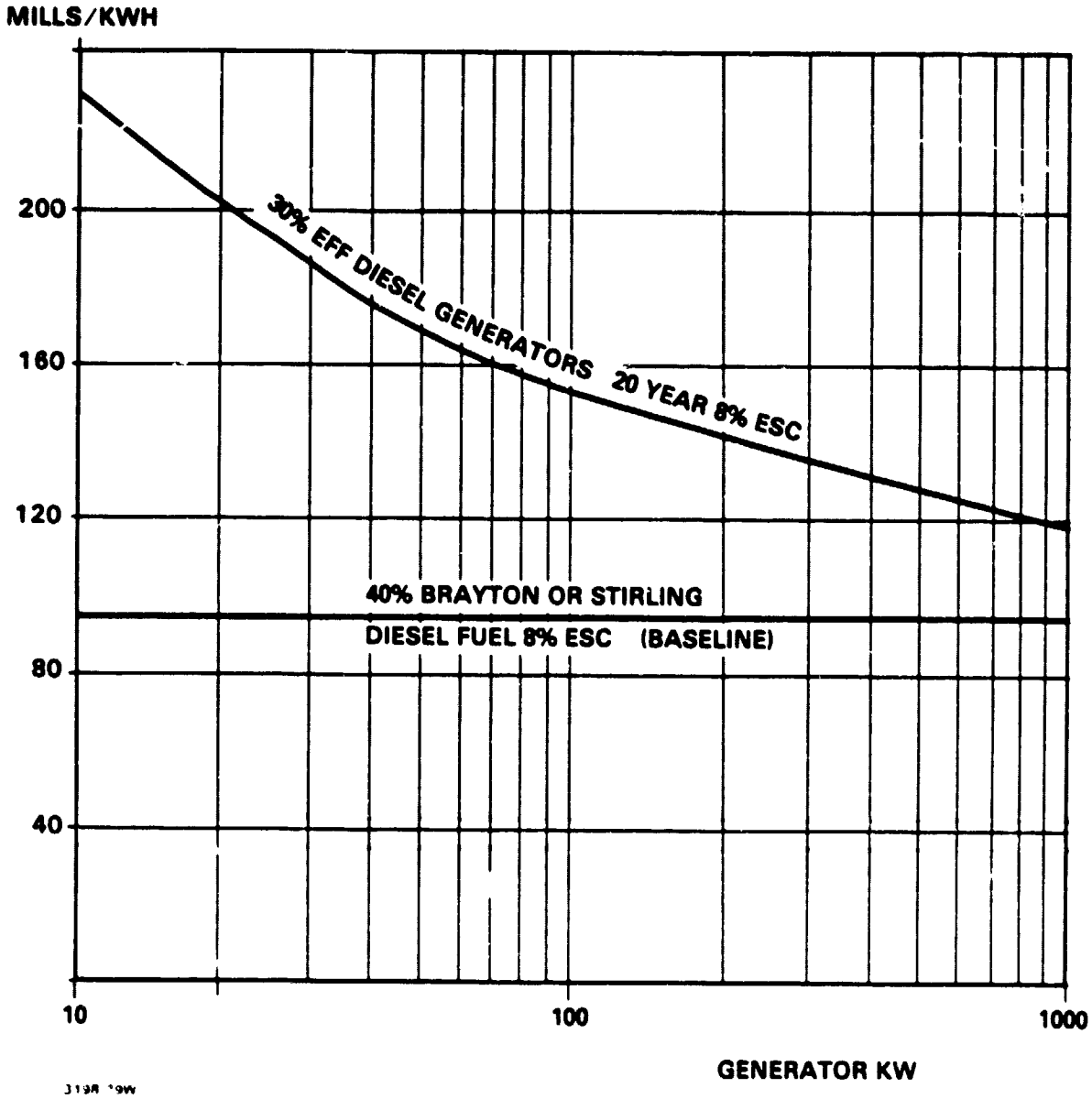
$KWH = (EUAC)/ANNUAL ENERGY PRODUCTION)

$$EUAC = CRF \cdot \left[C + \sum_{J=1}^{N} \left(M + (1 + E) \cdot F + H_J \right) \left(\frac{1 + G}{1 + D} \right)^J \right]$$

$$CRF = 1/PV_s = \left[\left(\frac{1 + D}{1 + G} \right) - 1 \right] \Big/ \left[1 - \left(\frac{1 + G}{1 + D} \right)^N \right] = \frac{(D - G)}{(1 + G) \left[1 - \left(\frac{1 + G}{1 + D} \right)^N \right]}$$

EUAC =EQUIVALENT UNIFORM ANNUAL COST.
CRF =CAPITAL RECOVERY FACTOR.
PV_s =PRESENT VALUE FACTOR OF A UNIFORM SERIES.
N =LIFE EXPECTANCY OF SYSTEM.
J =YEAR INDEXING VARIABLE.
C =CAPITAL COST OF SYSTEM.
D =DISCOUNT RATE.
M =O&M ANNUAL COST
G =GENERAL INFLATION RATE.
E =FUEL DIFFERENTIAL ESCALATION RATE.
F =ANNUAL FUEL COSTS.
H_j =OVERHAUL COST IF J IS A MULTIPLE OF MTBO;
= Ø OTHERWISE.
MTBO =MEAN TIME BETWEEN OVERHAULS.

ELECTRICITY — COST PROJECTIONS



COST METHODOLOGY II

$$A = \frac{PFS + [AOM + E + EOM + S + SOM]}{ASF}$$

A = $/(PEAK ARRAY KW) COLLECTOR COSTS.

PFS = PRESENT VALUE OF FUEL SAVED.

AOM = PRESENT VALUE OF COLLECTOR ARRAY O&M COSTS.

E = ENGINE COSTS.

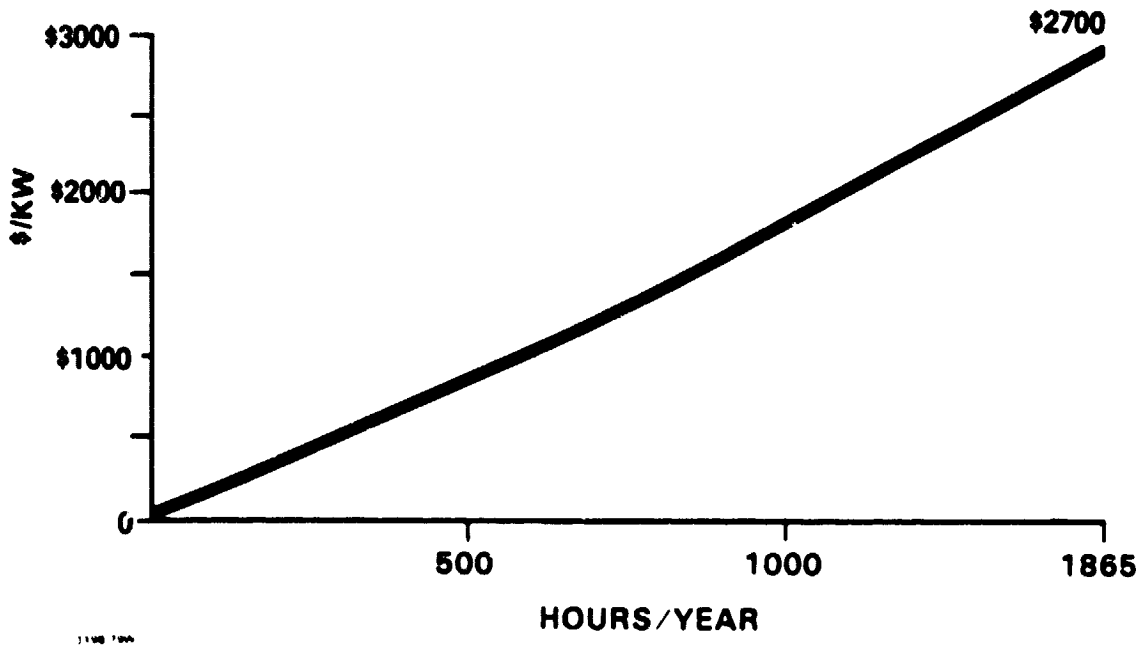
EOM = PRESENT VALUE OF ENGINE O&M COSTS.

S = STORAGE COSTS.

SOM = PRESENT VALUE OF STORAGE O&M COSTS.

ASF = ARRAY SIZING FACTOR.

THEATER SYSTEM COST GOALS



SYSTEM IMPLICATIONS: TACTICAL APPLICATIONS

TOTAL REPLACEMENT
RATE: 16 MW/YEAR + SMALLER UNITS
SYSTEM COST
GOAL: AT LEAST 120-210 MILLS/KWH, BASE CASE
ARRAY COST
GOALS: $2700/KW AT 1825 HOURS/YEAR

PLANT REQUIREMENTS IMPLICATIONS:

- VULNERABILITY TO VISUAL DETECTION, HARDNESS, AND SIZE AND WEIGHT REQUIREMENTS SEVERELY LIMIT SOLAR HEAT SOURCE POTENTIAL
- NOISE, IR, SIZE AND WEIGHT REQUIREMENTS FAVOR THE ENGINES ASSOCIATED WITH POINT FOCUSSING THERMAL AND ELECTRIC APPLICATIONS
- MULTI-FUEL REQUIREMENT FAVORS EXTERNAL HEAT ENGINES
- A SOLAR/MULTIFUEL CAPABLE PRIME MOVER WITH FRACTIONAL PROCUREMENT OF SOLAR COLLECTORS (E.G. 20 PERCENT) APPEARS OPERATIONALLY AND ECONOMICALLY FEASIBLE
- CENTRAL GENERATION OPERATIONALLY UNATTRACTIVE

SYSTEM IMPLICATIONS: REMOTE APPLICATIONS

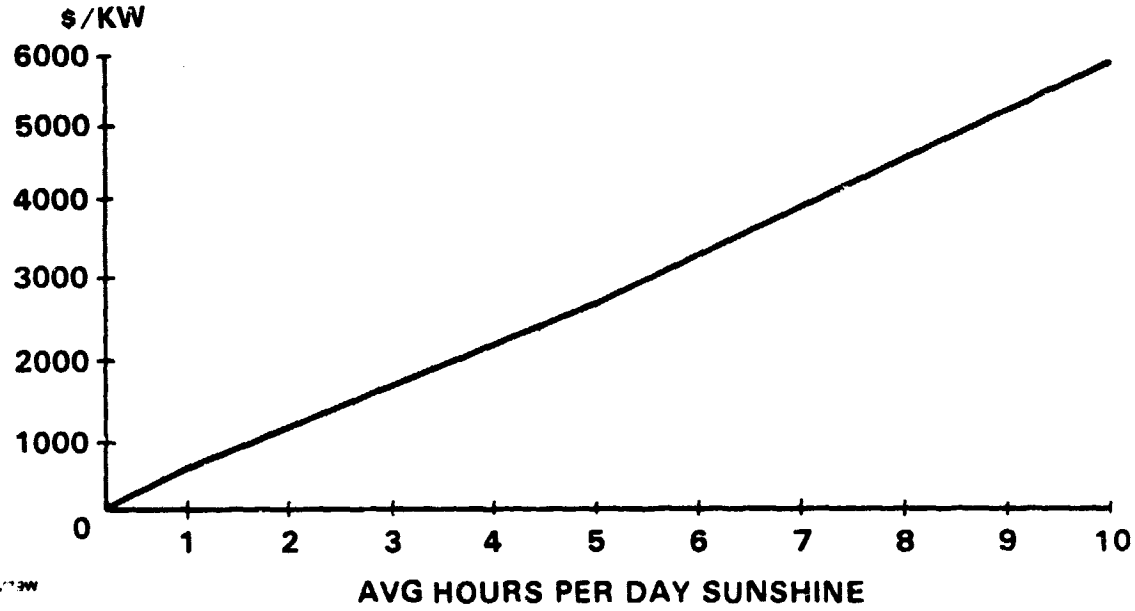
TOTAL SCOPE:	230 MW
SYSTEM COST GOAL:	$125-220 MILLS/KWH
ARRAY COST GOAL:	$2700/KW AT 1825 HOURS/YEAR

PLANT REQUIREMENTS IMPLICATIONS

- SOLAR SUFFERS LESS PENALTY FOR STORAGE BECAUSE CURRENT HIGH RELIABILITY REQUIRES STORAGE OR TWO INDEPENDENT SYSTEMS.
- MODULAR SOLAR SYSTEMS BENEFIT FROM REDUNDANCY IMPOSED BY HIGH AVAILABILITY REQUIREMENTS.
- STIRLING/SUBATMOSPHERIC BRAYTON MAINTENANCE ADVANTAGES OVER DIESEL MAY BE IMPORTANT
- HIGH COST OF FUEL DELIVERY A VARIABLE, ADDITIONAL PLUS TO ABOVE FIGURES.
- CENTRAL GENERATION SYSTEM HAS LARGER BACK-UP REQUIREMENT
- COGENERATION OF HEAT AN ATTRACTIVE BENEFIT

REMOTE SYSTEMS COST GOALS

- DIESEL GENERATOR ELECTRICITY 120-250 MILLS/KWH DEPENDING ON GENERATOR SIZE AND REDUNDANCY
- MODULAR HEAT ENGINE USING DIESEL FUEL



SYSTEM IMPLICATIONS: EMERGENCY/BACK-UP APPLICATIONS

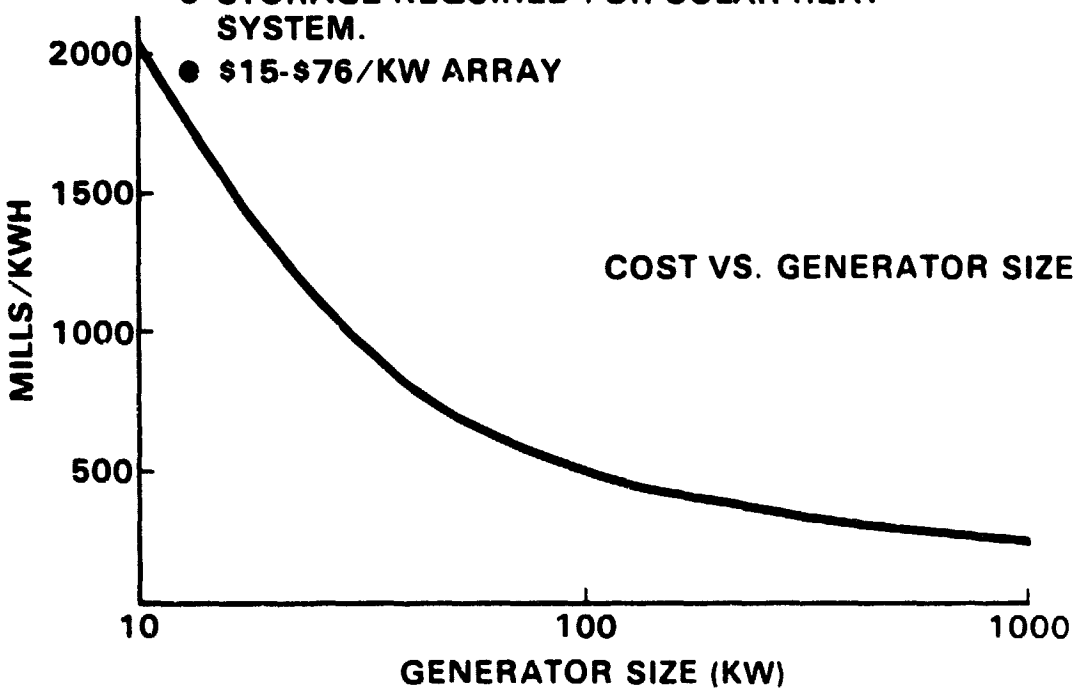
TOTAL SCOPE:	ESTIMATE 600 MW
SYSTEM COST GOALS:	250-1900 MILLS/KWH
ARRAY COST GOALS:	$76/KW (100%) $15/KW (20%)

PLANT REQUIREMENT IMPLICATIONS

- DUTY CYCLE IS INCONSISTENT WITH SOLAR AVAILABILITY UNLESS POWER IS UTILIZED FOR SOME OTHER FUNCTION, E.G. HEATING, AND DIVERTED FOR EMERGENCY ELECTRICITY.
- EMERGENCY SYSTEMS FAVOR LOW FIRST-COST POWER PLANTS
- A SINGLE, MODULAR SOLAR POWER PLANT CAN REPLACE A UTILITY HOOK-UP PLUS AN EMERGENCY SYSTEM.

EMERGENCY/BACKUP COST IMPLICATIONS AND GOALS

- DUTY CYCLE = ONE HOUR/DAY, 50 DAYS/YEAR PLUS 70 HOURS/YEAR.
- STORAGE REQUIRED FOR SOLAR HEAT SYSTEM.
- $15-$76/KW ARRAY

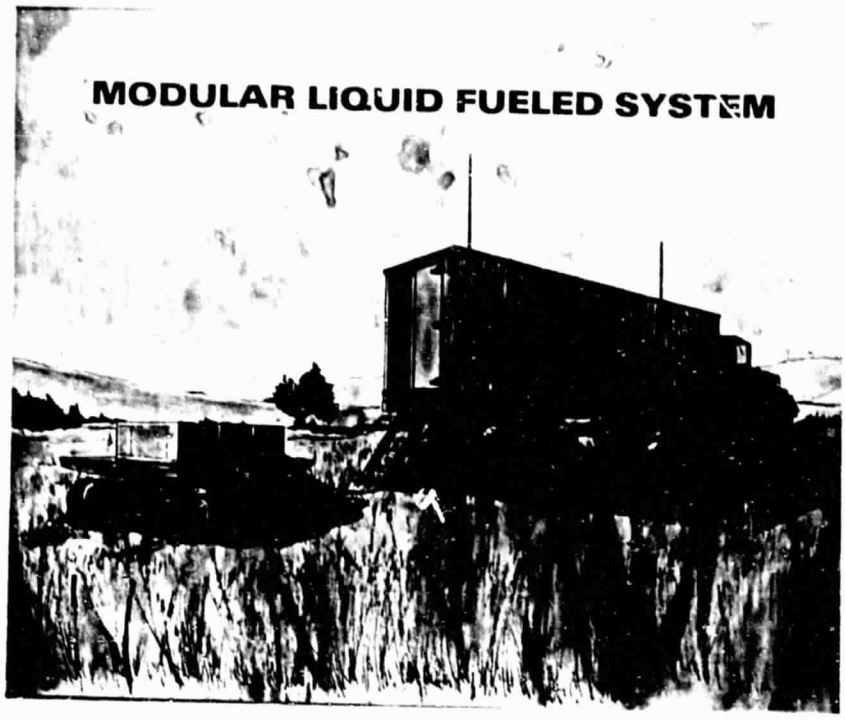


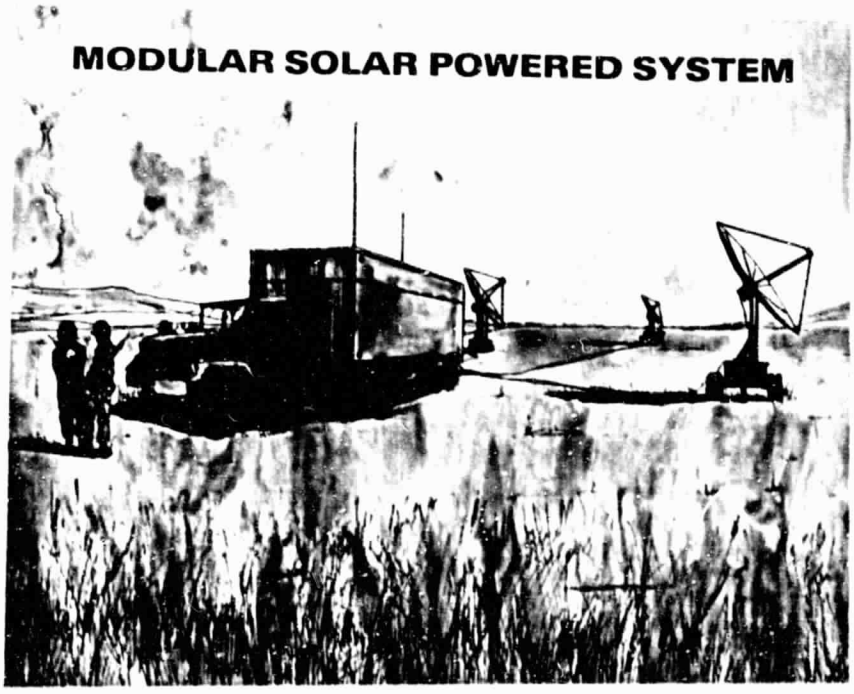
SYSTEM IMPLICATIONS: FACILITIES IMPLICATIONS

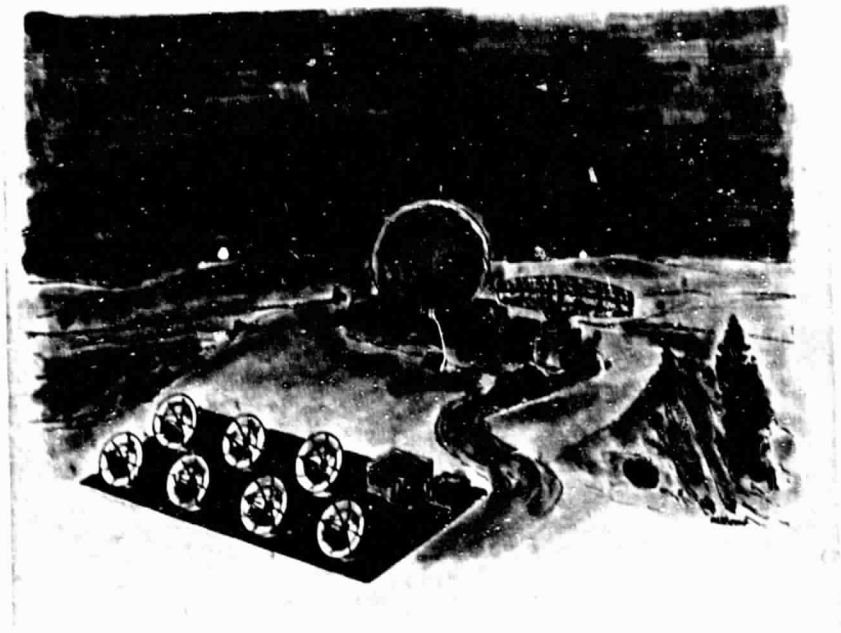
TOTAL REPLACEMENT RATE OUT OF 5000 KW:	REASONABLY 250 MW/YEAR
COST GOALS—86 MILLS/KWH:	$2500-2600/KW AT 1825 HOURS/YEAR
—90 MILLS/KWH:	$2500-2600/KW AT 1825 HOURS/YEAR

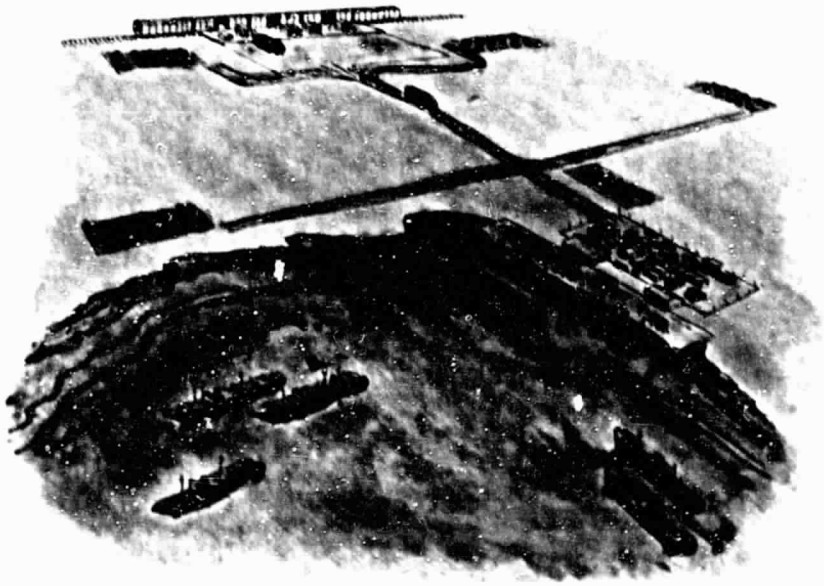
PLANT REQUIREMENT IMPLICATIONS:

- STEP SYSTEM CAN PROMOTE BASE SELF SUFFICIENCY
- FOR NEW FACILITIES, THE COST OF ON POST DISTRIBUTION CAN BE REDUCED AND CREDITED TO COST GOALS
- SELF SUFFICIENCY AND ECONOMIC BENEFITS GREATEST FOR CRITICAL FACILITIES WITH STANDBY REQUIREMENTS
- CONGRESSIONAL COMMITMENT TO CAPITAL INVESTMENT MAY OUTWEIGH OPERATIONAL CONSIDERATIONS


MODULAR LIQUID FUELED SYSTEM


MODULAR SOLAR POWERED SYSTEM





The following questions were directed to and answered by J. Scott Hauger, BDM:

Q. "Do you have an estimate of what cost differential the military might be willing to pay for reliability and independence?"

A. "No, not in terms of dollars. However, one key to marketing systems to the military is the generation of requirements documents. There are requirements documents that exist stating the benefits to the military without regard to technology. In terms of cost benefit analysis, I am not aware that they exist."

Q. "Naturally, one constraint has been and is Congressional support. Do you have a feel for the extent of Congressional commitment for this technology?"

A. "As an observation from the sidelines I can say that there are definitely persons in Congress that can have an impact on passing legislation for military applications of solar technology. It would appear that solar energy military technology would draw together some political interests by intersecting the circles of environmentalists, military procurement specialists, and solar energy supporters that exist in Congress. However, it would be futile to go further by predicting personal attitudes of Congressional supporters."

Q. "At the 10KW rating, a slide displayed that advanced Stirling and Brayton engines were better than a diesel by a factor of 3. Why is the military not frantically developing Stirling and Brayton systems?"

A. "Firstly, these figures were simply cost projections based on life cycle assumptions. Secondly in the 1960's when fuel was plentiful and the goal was silent power, the military showed significant interest in

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Stirling engines. Now there are competing technologies such as gas turbines, solar thermal, solar electric, fuel cells, diesels, as well as Stirling and Brayton engines. Each is at a different point of program development, hence many are not being considered competitive because of a lesser degree of development."

Q. "Do you think that the combination technology of solar thermal adds to the aforementioned technology sufficiently to raise interest?"

A. "There are persons here because they hold the opinion that it does. That is one reason for this workshop."

Q. "To this point no mention has been made concerning photovoltaic technology as being a competitor to point focusing thermal electric technology. It seems quite necessary to consider this alternative for the proposed military and industrial markets and to compare the relative merits of the two technologies. Shouldn't this be closely considered when identifying markets and applications?"

A. "Certainly this should be considered. Yet there <u>are</u> certain differences that are inherent to the marketing of these systems. The uniqueness of the point focusing system is that it is hybrid and fuel becomes the medium for storage. Photovoltaics have quite different requirements for electrical energy storage. Thus, the two cannot be compared solely by cost analysis. Their operational effectiveness becomes a critical comparison factor. A personal opinion is that photovoltaics are much better suited for applications less than 1KW than are solar thermal units. Larger applications are more difficult to compare and assess. However, for <u>portable</u> applications, photovoltaics cannot compete due to their storage requirements. This may also hold true for remote applications due to the cogeneration capability of solar thermal units.

Additional Comments

"In the interest of persons desiring to create a market for solar technology as well as those persons involved in R&D, the simple necessity to sell solar technology, whether it be solar electric, solar thermal, hybrid, etc., should be emphasized. Once this is done, the superior technology will emerge as a direct consequence. So perhaps efforts to predetermine the 'best' would be wisely directed towards creating a market. The type of disagreement between solar thermal and solar electric is much like the nonsensical bickering between the Army and the Navy. Our purpose should be to make solar technology real."

"Several things should be pointed out concerning the comparison of solar thermal units and photovoltaics. A consulting firm has been contracted to do this analysis and although the study is not yet complete, several results should be noted. It was found that the biggest problem of the competing technologies is, figuratively speaking, in the ditch. Solar thermal units often require a high degree of precision concerning concentrating ratios in order to achieve their high efficiency ratings. This is not true with photovoltaics. Yet even with the large tracking arrays needed for high efficiency solar thermal systems, they are still very competitive with photovoltaics."

"The other conclusion has been that small 5 or 6 meter less rigid dishes combined with Stirling engines can be more economically feasible than photovoltaics in the 1KW to 7KW region."

"It should be pointed out that the marketplace is so very complex that there is no way to possibly study all the different tradeoffs that must be made. Only the market environment will eventually show what technologies will penetrate. Hence, care should be taken at this point in assigning specific technologies to narrow markets. If one or the other technology is pushed too hard, the market will be distorted."

SOLAR THERMAL ELECTRIC POWER SYSTEMS
IMPACT ANALYSIS AND REQUIREMENTS DEFINITION STUDY

Dr. Yudi Gupta
Science Applications Inc.

Solar thermal electric power systems have the potential to supply power for industrial, commercial, institutional, and utility applications and to reduce consumption of non renewable fossil fuels. SAI is currently under contract to JPL to analyze the impacts of solar thermal electric systems and to define requirements in terms of system cost, performance, and design which are necessary for the development and utilization of solar electricity.

The original scope of the study was to address applications for solar thermal electric systems in the 1-10 MWe size range over the 1985-2000 time frame. This scope is currently under review for modification; however, the results to date and the discussion here relate primarily to electric-only applications in the 1-10 MWe range.

The impacts analysis and requirements definition of solar thermal electric systems is an extremely complex analysis for even a single application. Several key steps are involved. It is first necessary to evaluate the status of solar thermal electric technology, to identify promising applications, and to characterize important site/region variables. In addition, these interrelated tasks must be developed quantitatively in terms of system cost/performance models, load models and characterization of user energy and financial needs, and models on site/region characteristics including hourly weather tapes. It is then possible to perform detailed impact assessments and identify key system requirements.

The approach taken by SAI reflects each of the key steps. Because of the qualitative orientation of this workshop and the short time allotted, the emphasis here is on the general nature of the applications, the data requirements, and the key parameters which must be addressed for an effective solar thermal electric requirement definition.

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The major subsystems of a solar thermal electric plant include:

(1) concentrator

(2) receiver

(3) thermal and electrical transport

(4) thermal and/or electrical storage

(5) turbine/generator

(6) power conditioning and load/utility interface.

A variety of technologies are currently under investigation for each of these subsystems, each with its own set of design parameters and cost/performance characteristics. The presentation slides provide a few brief examples of collector design parameters, thermodynamic cycles, and current engine availability. Key environmental parameters that influence the system include meteorological variables such as insolation, temperature, humidity, pressure, etc., and cost drives such as soil bearing capability, seismic zone, and land availability.

These environmental parameters are directly related to regional considerations. Data profiles for each of the major meteorological variables have been derived by SAI for the U.S. based on hourly analysis of SOLMET weather tapes at 26 sites. Two primary parameters which affect system cost/performance are direct normal insolation and cost of conventional electricity. The cost-effectiveness (present worth) of a solar system for a given configuration is generally proportional to the product of these two parameters; hence, SAI has used this product as a cost-effectiveness parameter to develop, in conjunction with insolation, a regionalization of the U.S. for large grid-connected applications. As shown in the slides, direct normal insolation values for the U.S. range from 1200 to 2800 $KWH/m^2.y$; industrial electricity costs for 1976 ranged from .005 to .04 $/kWh; and the corresponding cost-effectiveness parameters ranged from a low of 5 $\$/m^2.y$ in Washington state (low insolation, low electricity costs) to a high of 60 $\$/m^2.y$ in Hawaii (high insolation, high electricity costs).

Total electrical energy consumption in the U.S. was about 2.10^{12} kwh in 1977 for approximately 90 million grid-connected customers. From the

average use per customer, it is clear that potential grid-connected applications of 1-10 MWe systems are primarily large commercial/industrial/institutional customers. However, various classes of applications have quite different energy requirements based on their key mission requirements. The profitability orientation of manufacturing establishments, for example, stands in sharp contrast to the defense mission of military installations or the concern of utilities for reliable power generation. As shown in the presentation slides, these differing mission requirements imply different concerns and issues for solar thermal electric power systems.

A detailed analysis of potential industrial applications was performed based on energy consumption, electricity costs, load shapes, insolation, and representative solar system performance and costs. For each 3-digit SIC code and state, the profitability of solar investment was calculated, and the resulting energy displaced was estimated based on user load shapes and conservative system sizing (turbine/generator output no more than average daytime demand). As expected, specific industry-state combinations look attractive because of high electricity costs and/or high insolation; with total market size also important. Land availability, which is also a key factor, was not addressed in this analysis because of insufficient data; nominal land costs were used in the economic analysis.

Load profiles are an important consideration for analyzing the impacts of solar thermal electric systems. SAI has developed a large data base of load profiles for various applications. In line with the interests of many of the workshop attendees, it is interesting to note that military installations provide a mix of activities whose energy demands are very similiar to civilian energy consumption patterns. Military loads reflect a mix of residential activities, 24-hours continuous industrial and equipment loads, and one or two shift administrative and commercial-type activities. Data is provided in the slides to illustrate these characteristics. Military installations are considered to be a favorable application because of the desire to be independent of utility outages, the availability of manpower for operation and maintenance, the availability of funding if mission

requirements are met, and the orientation towards long-term economics. However, a detailed analysis of design requirements (e.g., back-up energy) in relation to mission requirements has not yet been performed.

During the next fiscal year SAI will develop impact analyses and address the key issues for a requirements definition of solar electric systems. These issues will be addressed in relation to user energy requirements and site characteristics and will consider system design requirements, system cost requirements, subsystem performance and functional requirements, operational and maintenance requirements, and construction and installation considerations.

PRESENTATION OUTLINE

- OVERVIEW OF IMPACT ANALYSIS AND REQUIREMENTS DEFINITION STUDY
- SYSTEM PERFORMANCE CONSIDERATIONS
- REGIONAL CONSIDERATIONS
- APPLICATIONS CHARACTERISTICS
- NATURE OF SOLAR THERMAL ELECTRIC REQUIREMENTS DEFINITION

STUDY SCOPE

(CURRENTLY BEING MODIFIED)

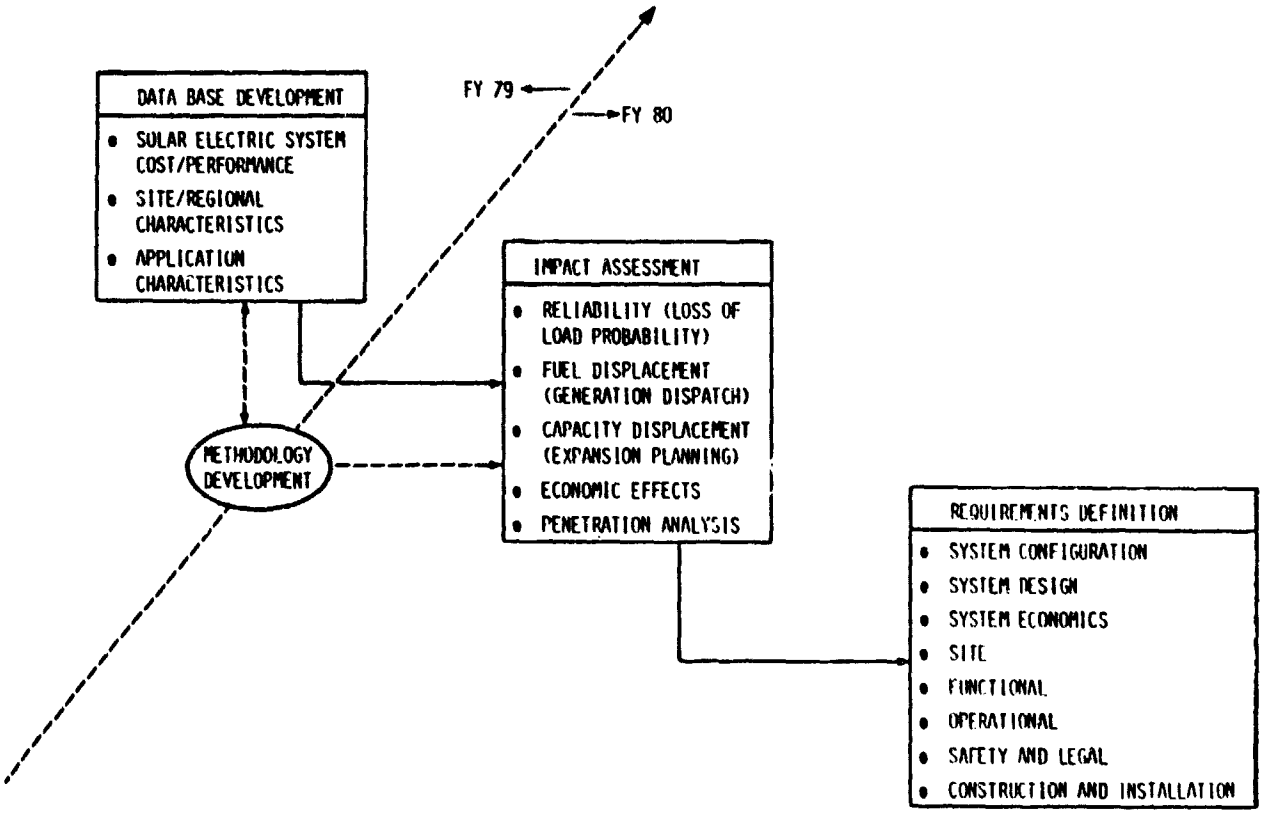
- 1 - 10 MW_E SOLAR THERMAL ELECTRIC SYSTEMS
- 1985 - 2000 TIME FRAME
- UNITED STATES APPLICATIONS
  - UTILITIES
  - INDIVIDUAL USERS
- DETAILED ANALYSIS OF
  - SYSTEM PERFORMANCE
  - SYSTEM COST PROJECTIONS
  - USER IMPACTS
  - DESIGN REQUIREMENTS

STUDY OBJECTIVES

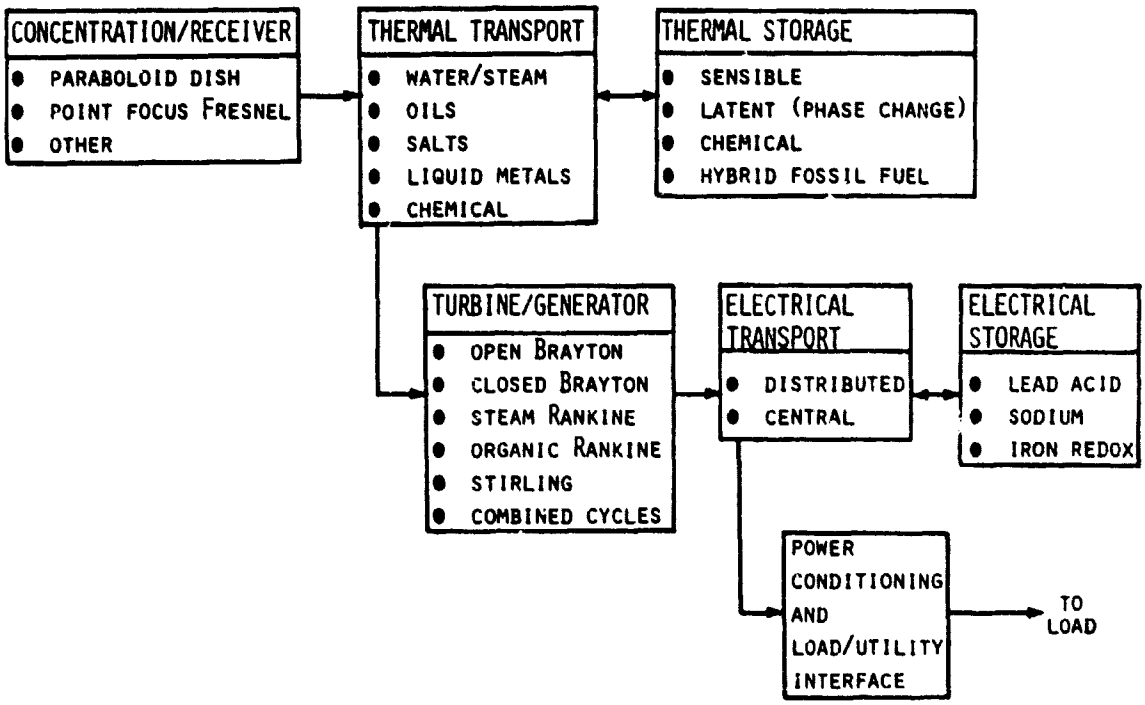
- ASSESS SOLAR THERMAL ELECTRIC TECHNOLOGY STATUS AND DEVELOP PERFORMANCE/COST MODELS
- IDENTIFY POTENTIAL APPLICATIONS OF SOLAR THERMAL ELECTRIC POWER
- EVALUATE IMPACTS OF SOLAR THERMAL ELECTRIC SYSTEMS ON
  - UTILITIES
    - LARGE UTILITIES
    - SMALL UTILITIES
    - DISPERSED ON-SITE GENERATION
  - INDIVIDUAL LOADS
    - GRID-CONNECTED
    - GRID-ISOLATED
- ASSESS DESIGN REQUIREMENTS FOR SOLAR THERMAL ELECTRIC SYSTEMS
  - SYSTEM CONFIGURATIONS
  - SYSTEM DESIGN PARAMETERS
    - COLLECTOR
    - STORAGE
    - TURBINE GENERATOR
    - DISPATCH STRATEGY
  - FUNCTIONAL CHARACTERISTICS
  - OPERATION AND MAINTENANCE
  - CONSTRUCTION AND INSTALLATION
  - SITE REQUIREMENTS
  - SAFETY AND LEGAL ISSUES

SOLAR THERMAL ELECTRIC POWER SYSTEMS

KEY STEPS NECESSARY FOR SYSTEM REQUIREMENTS DEFINITION



GENERIC SOLAR THERMAL ELECTRIC GENERATING PLANT



POTENTIAL CONFIGURATIONS

DISTRIBUTED GENERATION MODE

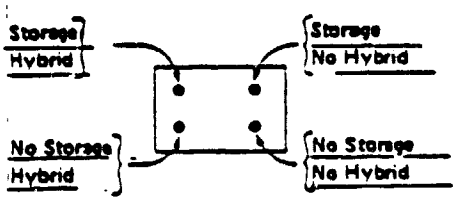
COLLECTOR/ RECEIVER SYSTEM	THERMODYNAMIC CYCLE					
	BRAYTON OPEN	BRAYTON CLOSED	STIRLING	RANKINE	RANKINE THROUGH STORAGE	COMBINED
Heliostat Field						
Parabolic Dish	● ● ● ●	● ● ● ●	● ● ● ●			● ● ● ●
Parabolic Trough						
Fixed Mirror						

● Electrical Transport

CENTRAL GENERATION MODE

COLLECTOR/ RECEIVER SYSTEM	THERMODYNAMIC CYCLE					
	BRAYTON OPEN	BRAYTON CLOSED	STIRLING	RANKINE	RANKINE THROUGH STORAGE	COMBINED
Heliostat Field	⊙ ⊙ ● ●	⊙ ⊙ ● ●	⊙ ⊙ ● ●	⊙ ⊙ ● ●	⊙ ⊙ ● ●	⊙ ⊙ ● ●
Parabolic Dish	○ ○	○ ○	○ ○	⊙ ⊙ ● ●	⊙ ⊙ ● ●	○ ○
Parabolic Trough				● ● ● ●	● ● ● ●	
Fixed Mirror				● ● ● ●	● ● ● ●	

● Thermal Transport
○ Chemical Transport



DISH COLLECTOR PERFORMANCE PARAMETERS

$$P_{TET}(t) = A \cdot I(t) \cdot \eta_C(t) \cdot \eta_R(Q_C, Q_{RL}) \cdot \eta_{TET}(Q_R)$$

POWER OUTPUT OF THERMAL TRANSPORT SUBSYSTEM

COLLECTOR AREA

DIRECT INSOLATION

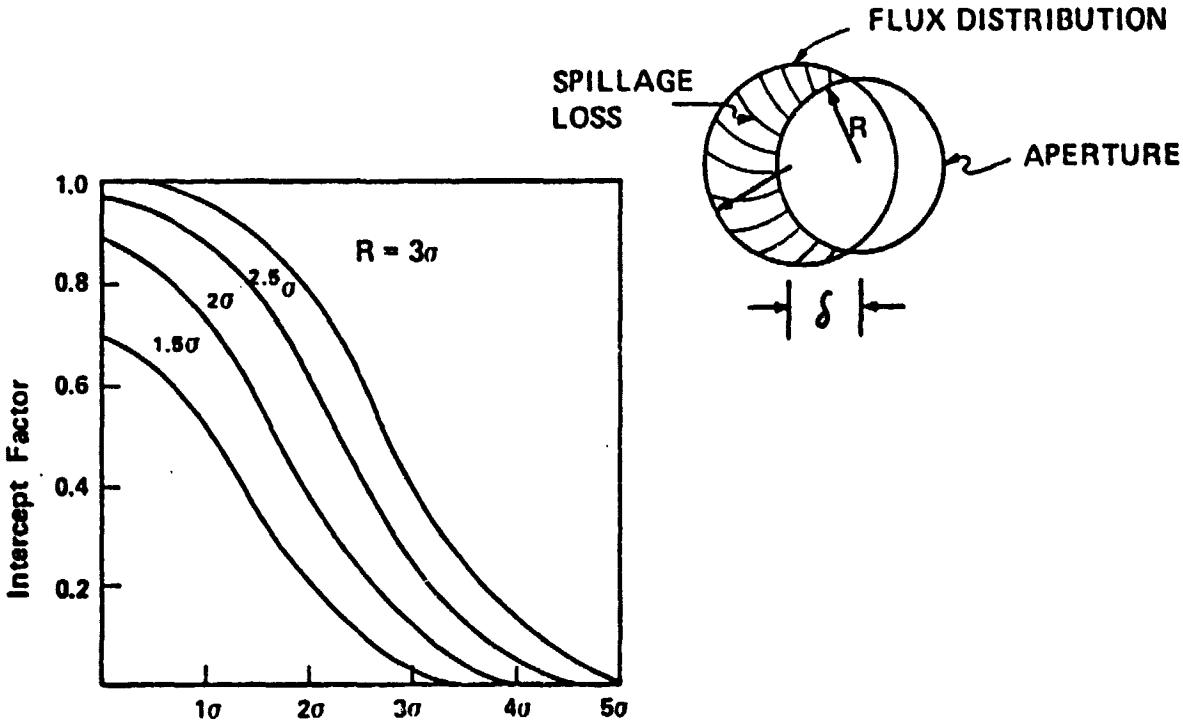
CONCENTRATOR EFFICIENCY
- OPTICS
  - REFLECTIVITY
  - TRANSMISSIVITY
  - ATMOSPHERIC ATTENUATION
- INTERCEPT FACTOR
  - SURFACE ERRORS
  - TRACKING ERRORS
  - APERTURE SIZE
  - OPTICAL LOSSES
- GEOMETRY
  - COSINE LOSSES
  - SHADING

RECEIVER EFFICIENCY
- ABSORPTIVITY
- RERADIATION LOSSES
- CONVECTION LOSSES

THERMAL TRANSPORT EFFICIENCY
- PUMPING LOSSES
- THERMAL LOSSES

COLLECTOR PERFORMANCE

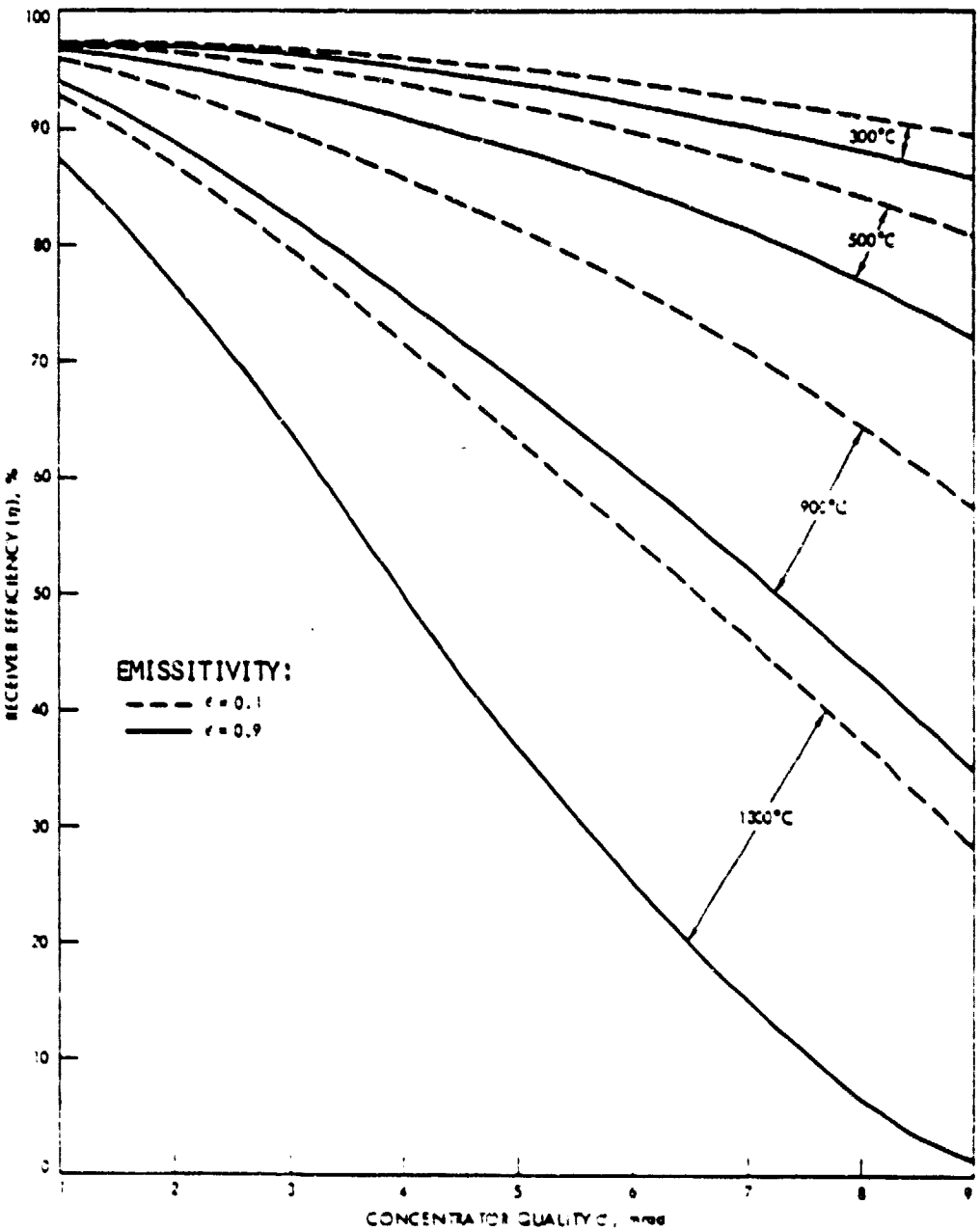
TYPICAL DISH RECEIVER INTERCEPT FACTOR



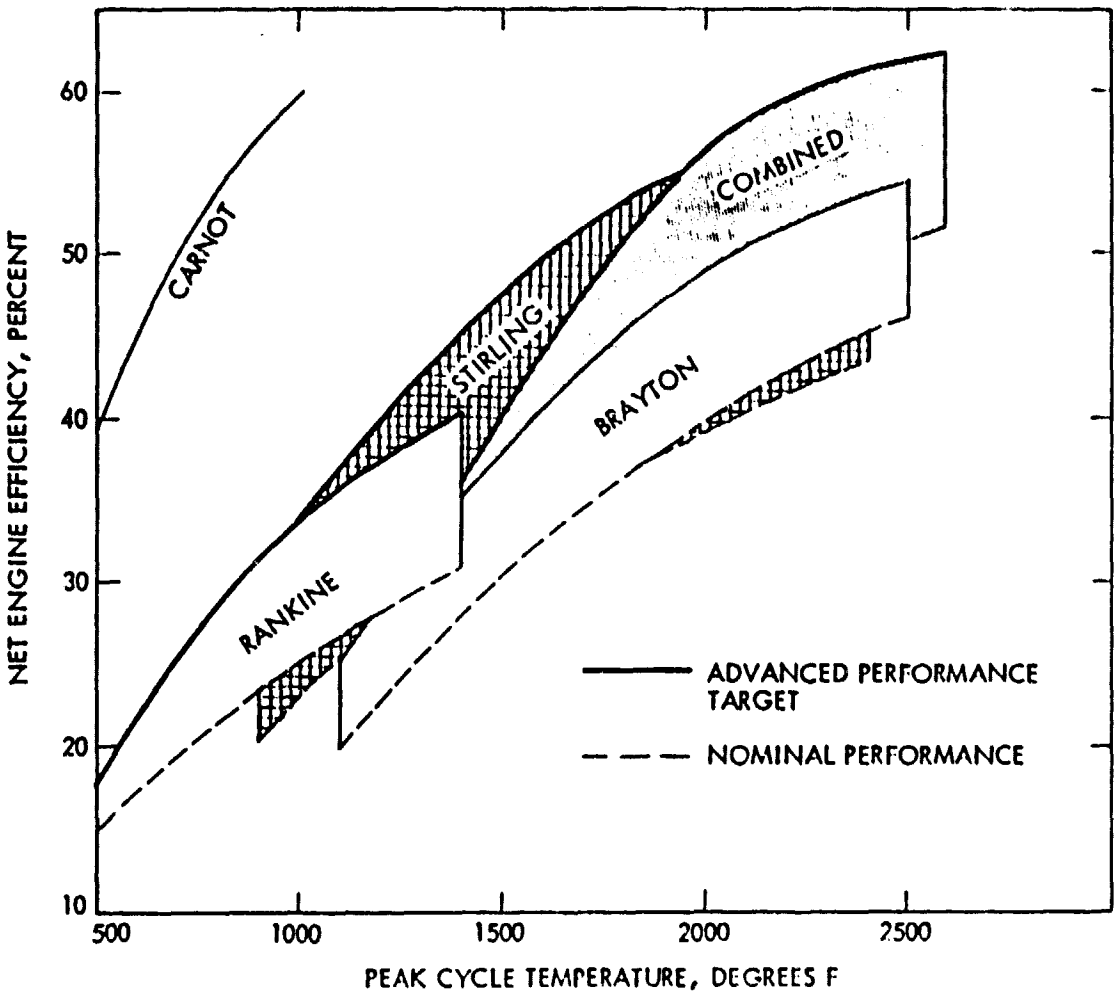
(σ IS STD. DEV. OF FLUX DIST.)

COLLECTOR PERFORMANCE (CONTINUED)

TYPICAL DISH RECEIVER EFFICIENCY VERSUS CONCENTRATOR QUALITY AND TEMPERATURE (JPL DATA)



TYPICAL HEAT ENGINE EFFICIENCIES



TURBINE GENERATOR PERFORMANCE (CONTINUED)

UNITED STIRLING P-40 ENGINE EFFICIENCY CURVE

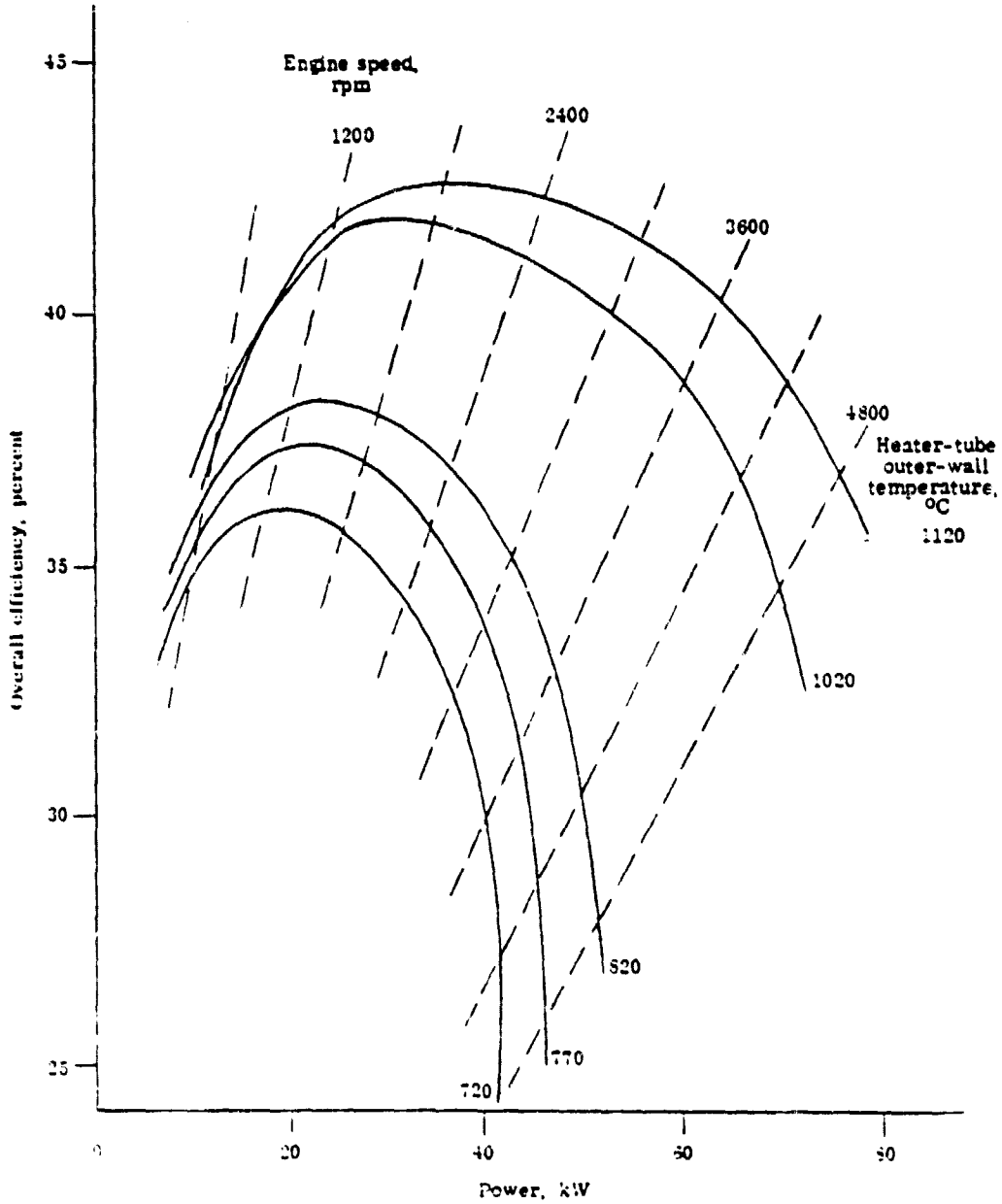
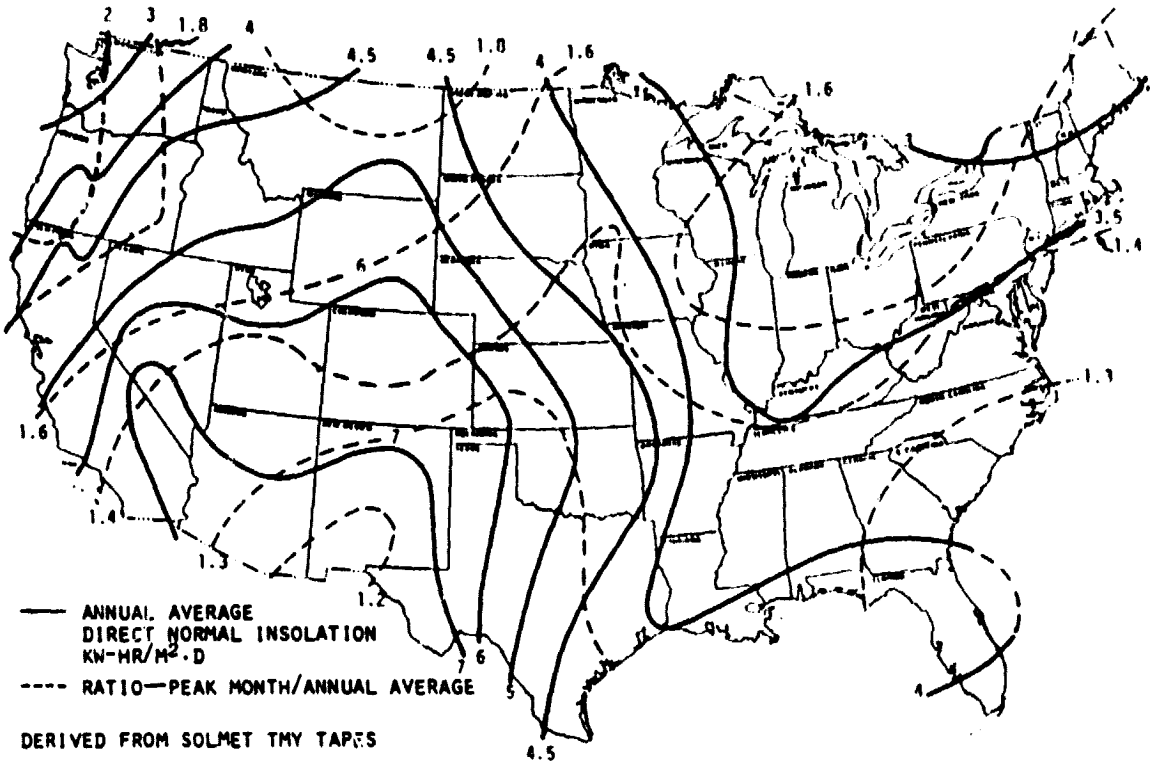


FIGURE: [illegible]-LEWIS DATA

SOLAR ELECTRIC SYSTEM COST/PERFORMANCE REGIONAL ENVIRONMENTAL PARAMETERS

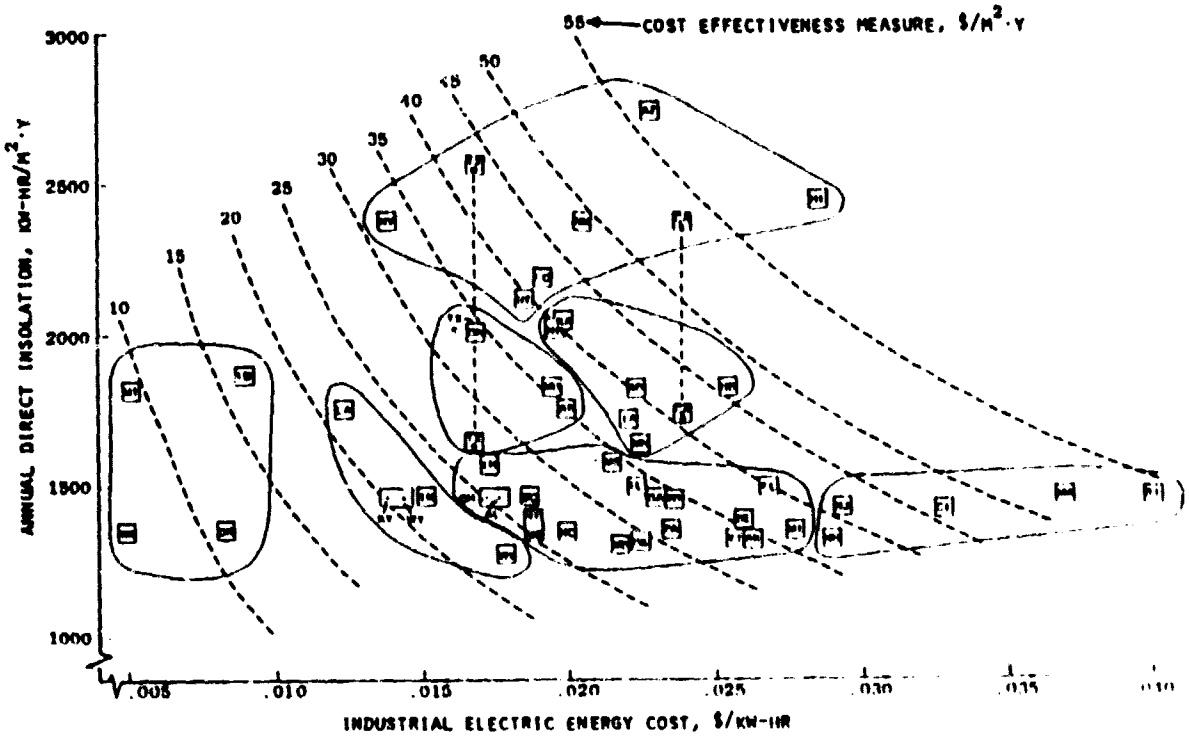
- SYSTEM PERFORMANCE
  - DRY BULB TEMPERATURE
  - WET BULB TEMPERATURE
  - PRESSURE
  - SUN POSITION
  - INSOLATION
  - ATMOSPHERIC ATTENUATION
  - WIND VELOCITY
  - CLOUD COVER FLUCTUATIONS
  - WATER AVAILABILITY
- SYSTEM COST
  - SOIL BEARING—FOUNDATIONS
  - SEISMIC ZONE—FOUNDATIONS
  - DESIGN WIND SPEED
  - LAND AND LABOR COSTS
- SYSTEM ECONOMICS
  - COST OF CONVENTIONAL ELECTRICITY
  - COST OF BACKUP ENERGY AND CAPACITY

REGIONAL INSOLATION CONTOURS

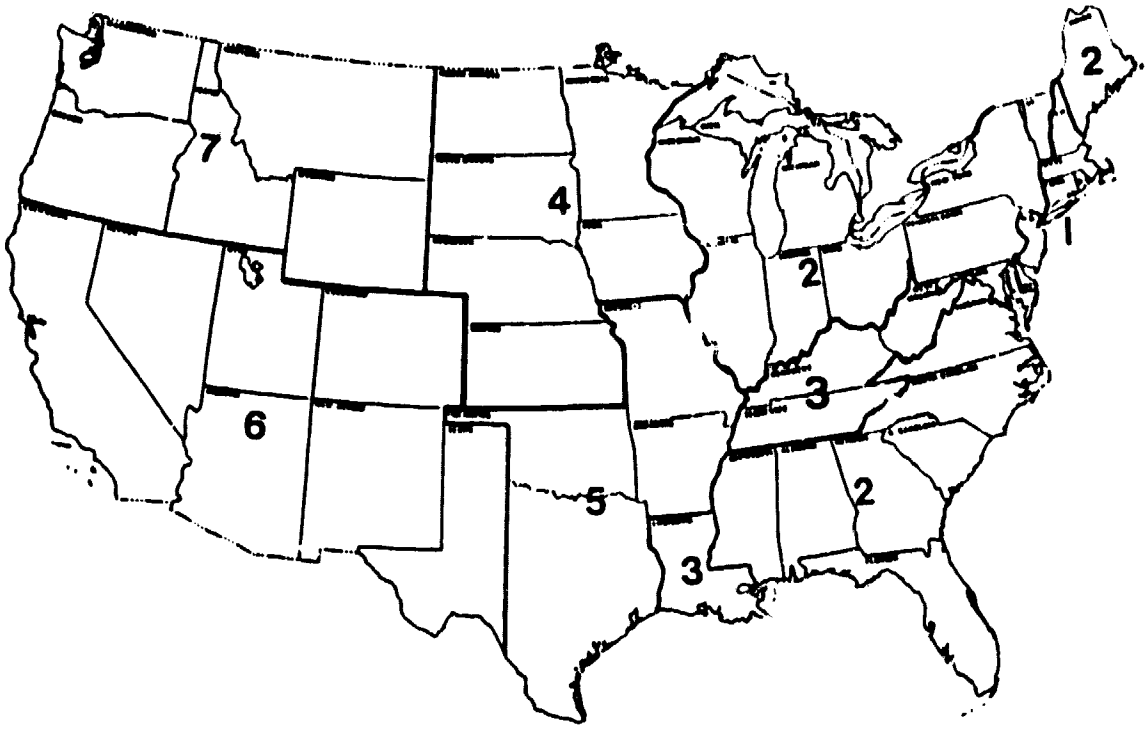


SCATTER PLOT

INSOLATION VERSUS INDUSTRIAL ELECTRICITY COST BY STATE



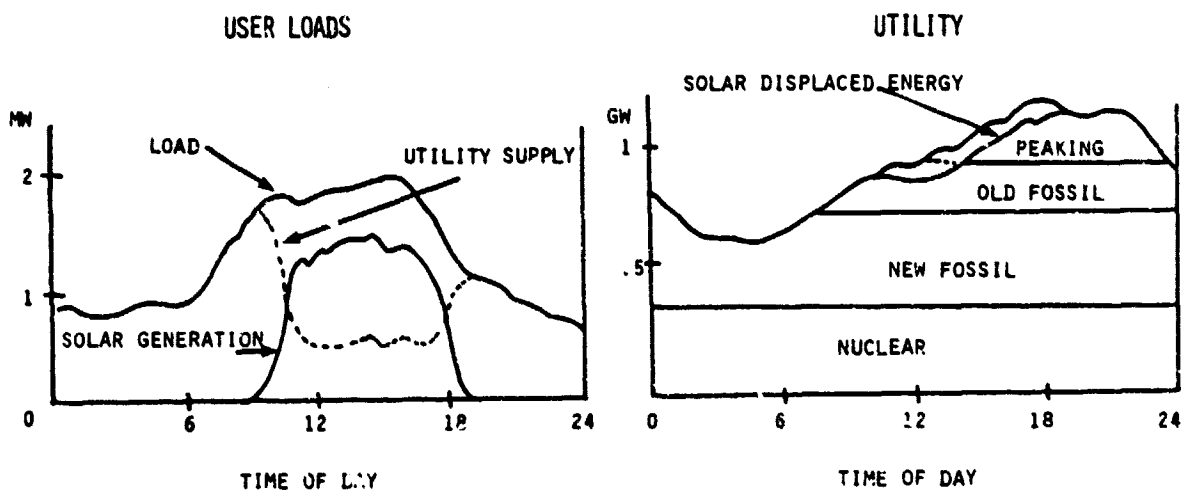
REGIONAL DIVISIONS BASED ON COST-EFFECTIVENESS CRITERION



1-10 MWe SOLAR THERMAL APPLICATIONS
COMPARISON OF KEY ISSUES

APPLICATION AREA	MISSION	KEY ISSUES
UTILITIES/LOAD CENTERS	PROVIDE RELIABLE POWER AT REASONABLE COST	• RELIABILITY • FUEL AVAILABILITY • FUEL DISPLACEMENT OF SOLAR • CAPACITY DISPLACEMENT OF SOLAR • ENVIRONMENTAL POLLUTION • PERFORMANCE DEMONSTRATION • LIFE CYCLE COSTING
MANUFACTURING	MANUFACTURE AND SELL PRODUCTS PROFITABLY	• NEAR-TERM PROFITABILITY • NEGATIVE CASH FLOW
COMMERCIAL	PROVIDE PRODUCTS/ SERVICES PROFITABLY	• NEAR-TERM PROFITABILITY • CAPITAL AVAILABILITY • OPERATION AND MAINTENANCE • BUYER PERCEPTION
INSTITUTIONAL	PROVIDE REQUIRED SERVICES (E.G., EDUCATION, ADMINISTRATION)	• PUBLIC SUPPORT • FUNDING AVAILABILITY • OPERATION AND MAINTENANCE • COST EFFECTIVENESS
MILITARY	MAINTAIN DEFENSE CAPABILITY	• MISSION REQUIREMENTS • OPERATIONAL REQUIREMENTS • DEPENDABILITY • BACKUP SUPPLY • LIFE CYCLE COSTING

IMPACT OF SOLAR ELECTRIC SYSTEMS



INDUSTRIAL APPLICATIONS

- KEY PARAMETERS FOR RANKING BASED ON PROFITABILITY AND ENERGY DISPLACEMENT
  - REGIONAL INSOLATION (BY STATE)
  - USER COST OF ENERGY (BY STATE AND SIC CODE)
  - USER ENERGY CONSUMPTION (BY STATE AND SIC CODE)
  - USER LOAD SHAPE (BY SIC CODE)
  - LAND AVAILABILITY*
  - SOLAR SYSTEM PERFORMANCE/COST

---

*CONSIDERED TO BE A KEY FACTOR BUT DATA DIFFICULT TO OBTAIN.

INDUSTRIAL APPLICATIONS
SUMMARY OF RANKING RESULTS

- FAVORABLE LOCATIONS
  - BASED ON ENERGY DISPLACED BY SOLAR:
    - CALIFORNIA
    - MASSACHUSETTS
    - ARIZONA
    - NEW JERSEY
    - TEXAS
  - BASED ON RETURN ON INVESTMENT:
    - HAWAII
    - CALIFORNIA } HIGH INSOLATION
    - ARIZONA
    - MASSACHUSETTS
    - NEW JERSEY } HIGH ENERGY COSTS

- FAVORABLE INDUSTRY GROUPS
  - BASED ON ENERGY DISPLACED BY SOLAR:
    - IRON AND STEEL INDUSTRIES
    - MOTOR VEHICLE INDUSTRIES
    - PLASTICS
    - INDUSTRIAL CHEMICALS
    - AIRCRAFT INDUSTRIES
    - CONCRETE AND CEMENT
  - BASED ON RETRUN ON INVESTMENT:
    - SAW MILLS AND PLANING MILLS
    - WOOD PRODUCTS
    - PRINTING AND PUBLISHING

    } VERY HIGH ENERGY COSTS IN A PARTICULAR STATE

INDUSTRIAL APPLICATIONS
SUMMARY OF MARKET PENETRATION ANALYSIS

- SOLAR THERMAL ELECTRIC SYSTEMS HAVE POTENTIAL APPLICATIONS IN MANY INDUSTRIES
- SOLAR ELECTRIC SYSTEMS MAY BECOME ECONOMIC IN THE 1985-1995 TIME PERIOD IF COST GOALS ARE MET
- SPECIFIC INDUSTRY-STATE COMBINATIONS LOOK ATTRACTIVE BECAUSE OF HIGH ELECTRICITY COSTS AND/OR HIGH INSOLATION
- ADDITIONAL KEY FACTORS INCLUDE
  - LAND AVAILABILITY
  - TAX INCENTIVES/FEDERAL LOAN PROGRAMS
  - PROJECTED SYSTEM COST AND PERFORMANCE
- LOAD SHAPE AND MAGNITUDE ARE KEY FACTORS IN DETERMINING SYSTEM SIZING AND THE RESULTANT ENERGY DISPLACED BY SOLAR
- LOAD SHAPE IS NOT A MAJOR DETERMINANT OF SOLAR ECONOMICS FOR GOOD DESIGNS (ASSUMING THERE IS A SIGNIFICANT DAYTIME LOAD)

HOURLY LOAD PROFILE DATA BASE

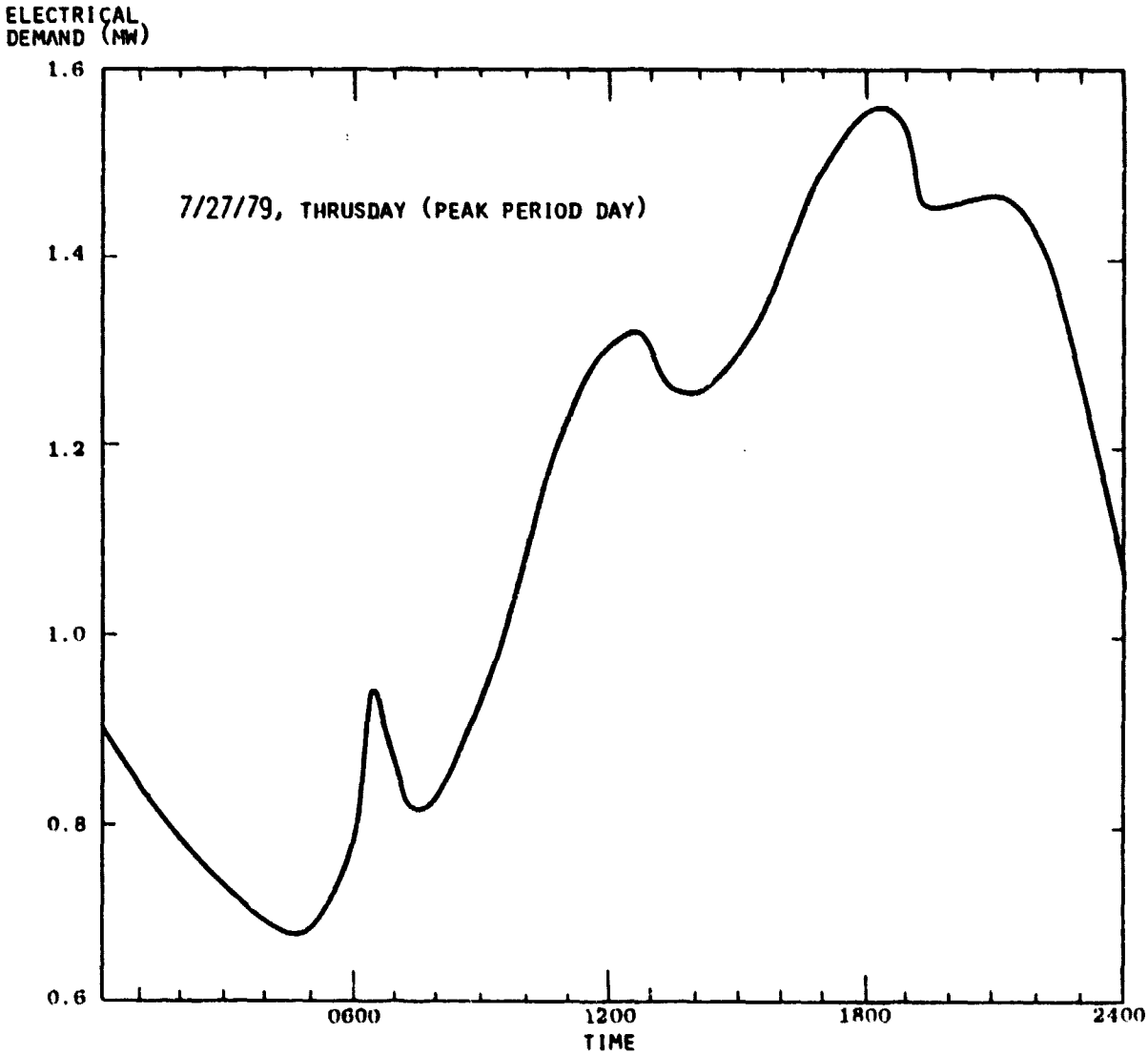
LARGE GRID-CONNECTED LOADS (PEAK DEMAND ≥ 0.5 MW)	• 130 CUSTOMERS BY 4-DIGIT SIC CODE • 1/2-HOURLY VALUES FOR FULL YEAR
INTERMEDIATE LOADS (0.05 - 0.5 MW)	• 100 AGGREGATED LOADS BY 2-DIGIT SIC CODE • 1/2-HOURLY VALUES FOR FULL YEAR
UTILITIES	• SMALL AND LARGE SYNTHETIC UTILITIES • SEASONAL AVERAGE DAILY PROFILES
MILITARY BASES	• SEASONAL AVERAGE AND/OR TYPICAL DAY PROFILES
OTHER (AGRICULTURAL, RESIDENTIAL, PARKS...)	• SELECTED PROFILES

CASE STUDY

MILITARY INSTALLATIONS ENERGY CHARACTERISTICS

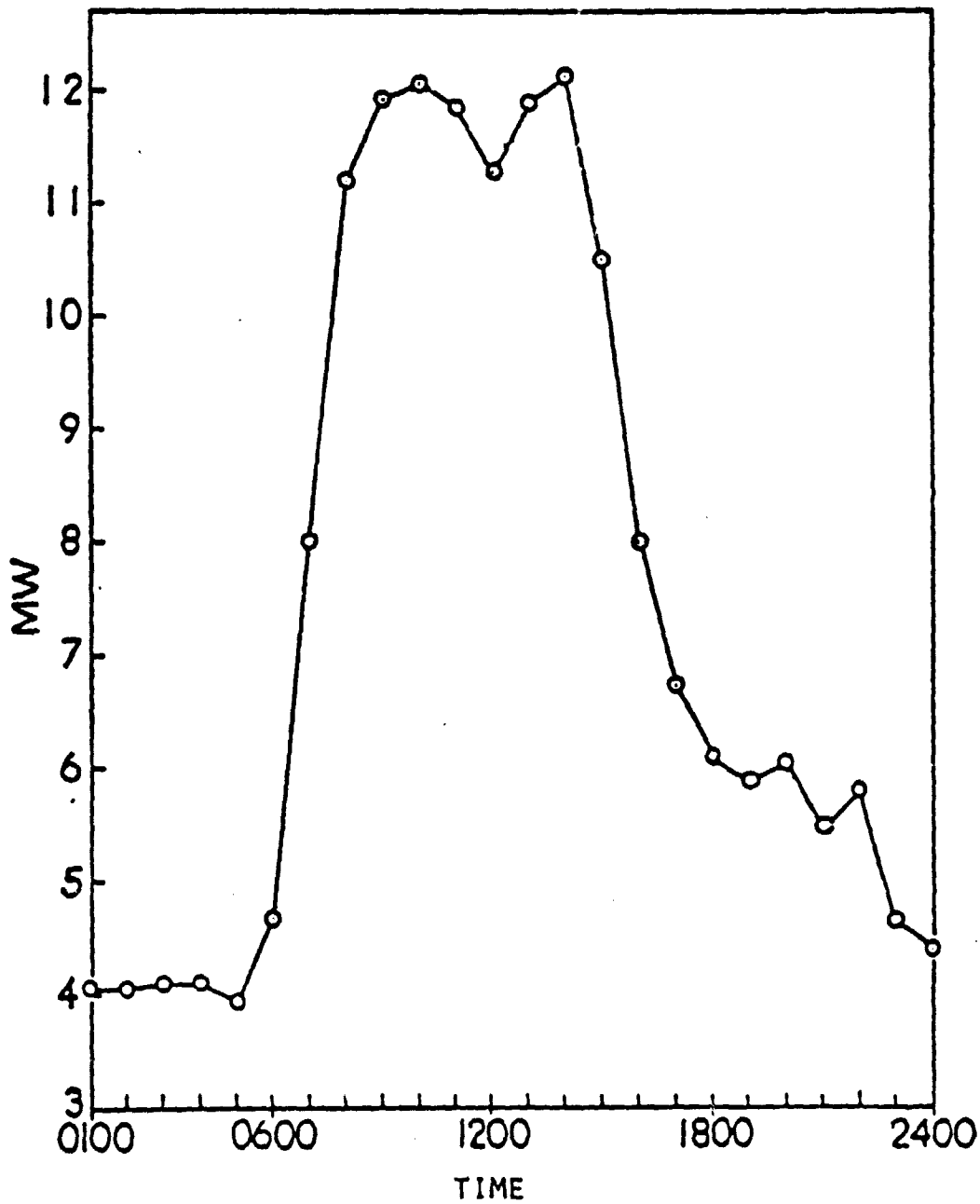
- MILITARY INSTALLATIONS PROVIDE A MIX OF ACTIVITIES WHOSE ENERGY DEMANDS ARE SIMILAR TO CIVILIAN ENERGY CONSUMPTION PATTERNS
  - RESIDENTIAL LOADS
    - DIVERSE ELECTRICAL
    - COOLING
    - HEATING
  - 24-HOUR CONTINUOUS LOADS
    - INDUSTRIAL LOADS
    - EQUIPMENT LOADS
  - DAYTIME LOADS
    - ADMINISTRATIVE
    - COMMERCIAL
    - ONE OR TWO SHIFT ACTIVITIES

TYPICAL RESIDENTIAL LOAD



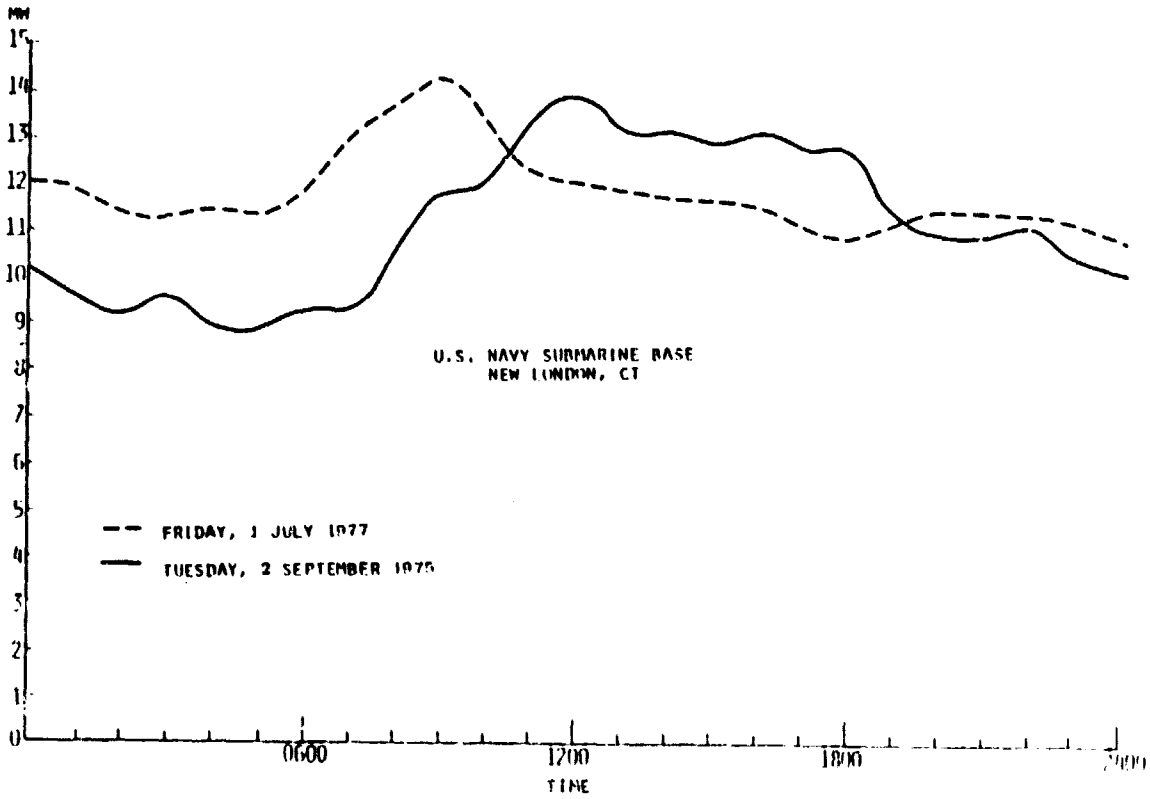
DEMAND PROFILE, BELLEVUE HOUSING, DC

TYPICAL SINGLE SHIFT LOAD WITH SOME 24-HOUR ACTIVITIES

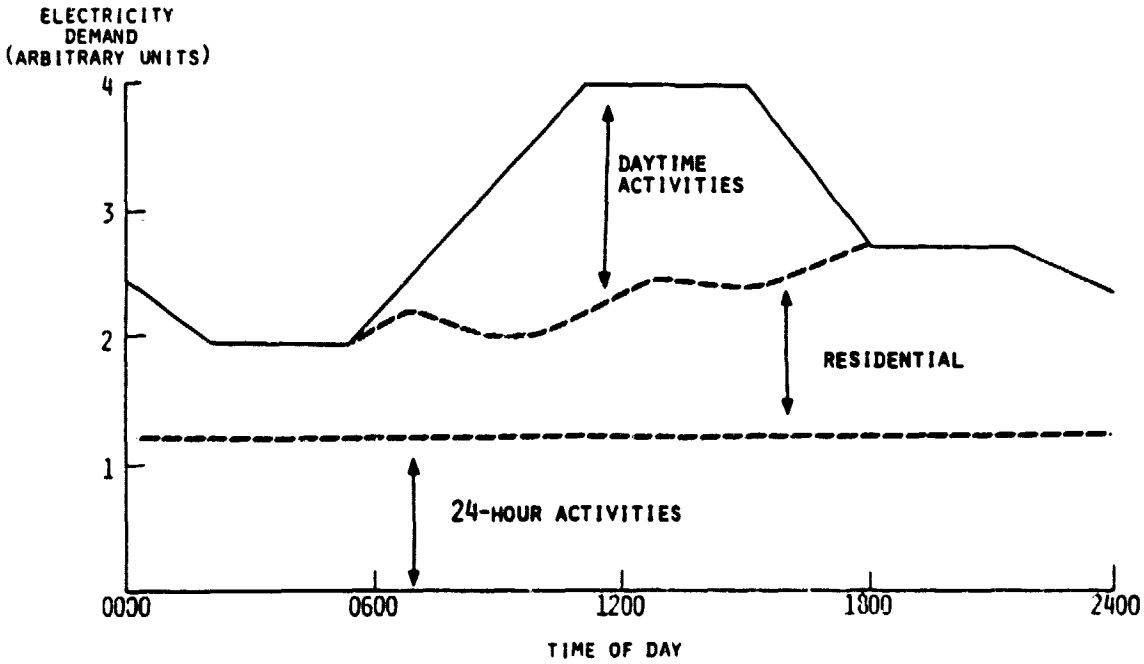


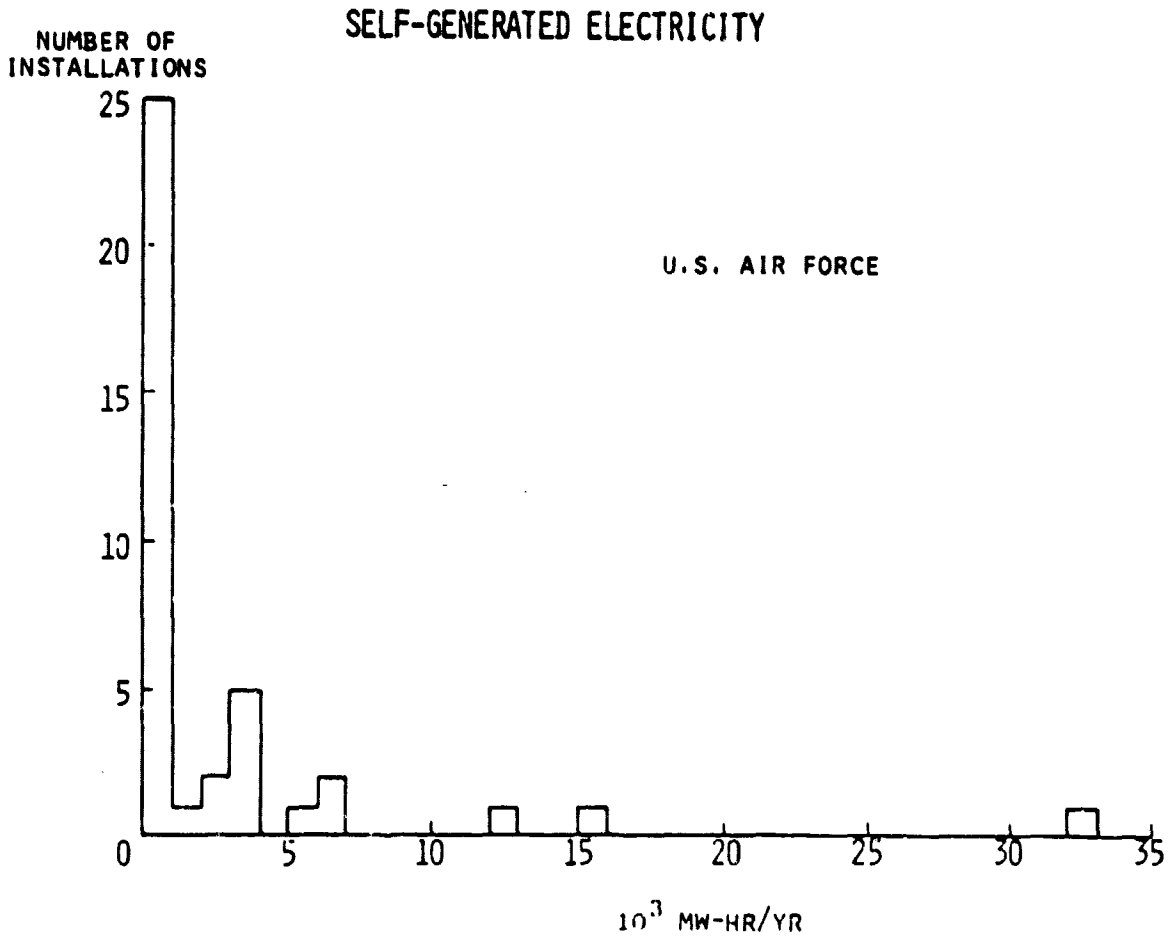
ELECTRICAL DEMAND, ROCK ISLAND ARSENAL
(ANNUAL COMPOSITE)

TYPICAL 3-SHIFT, 24-HOUR LOADS



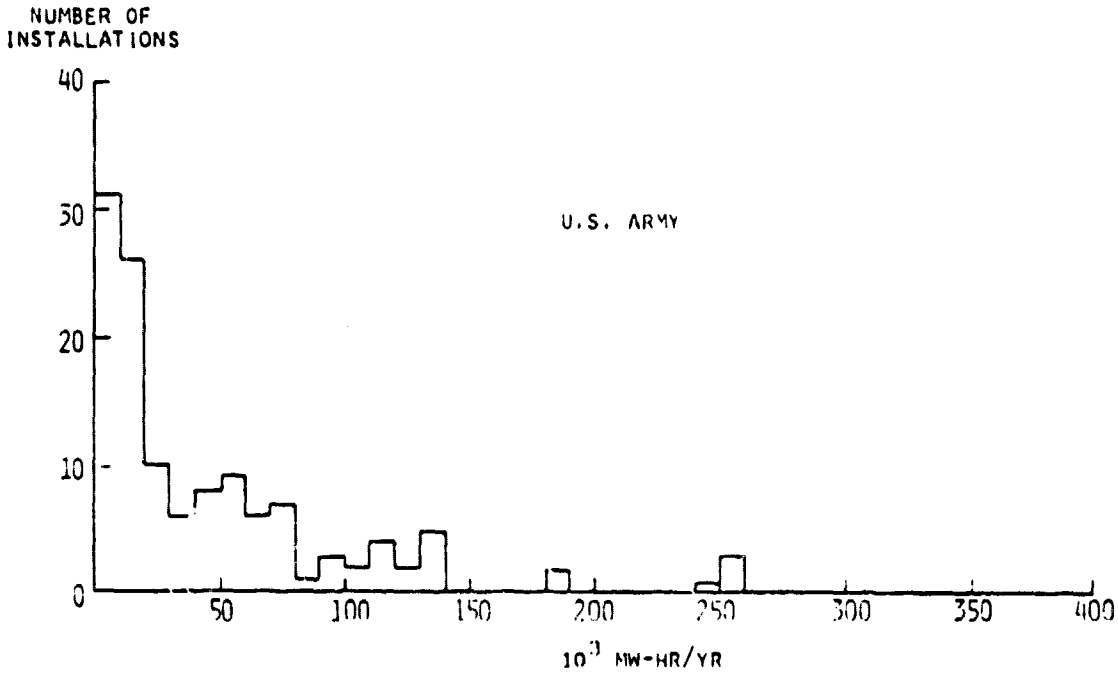
GENERIC MILITARY/CIVILIAN INSTALLATION LOAD PROFILE MODEL

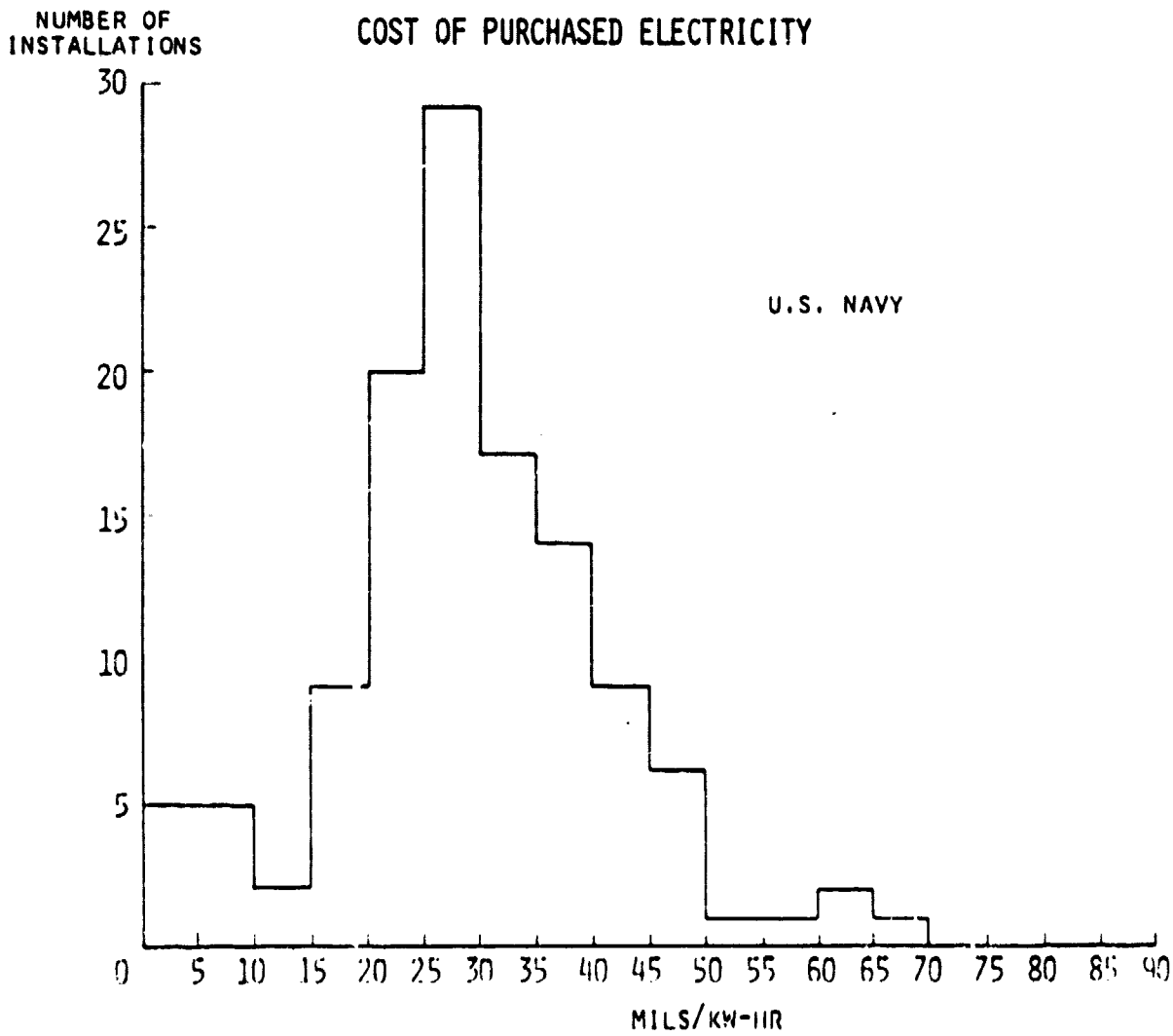


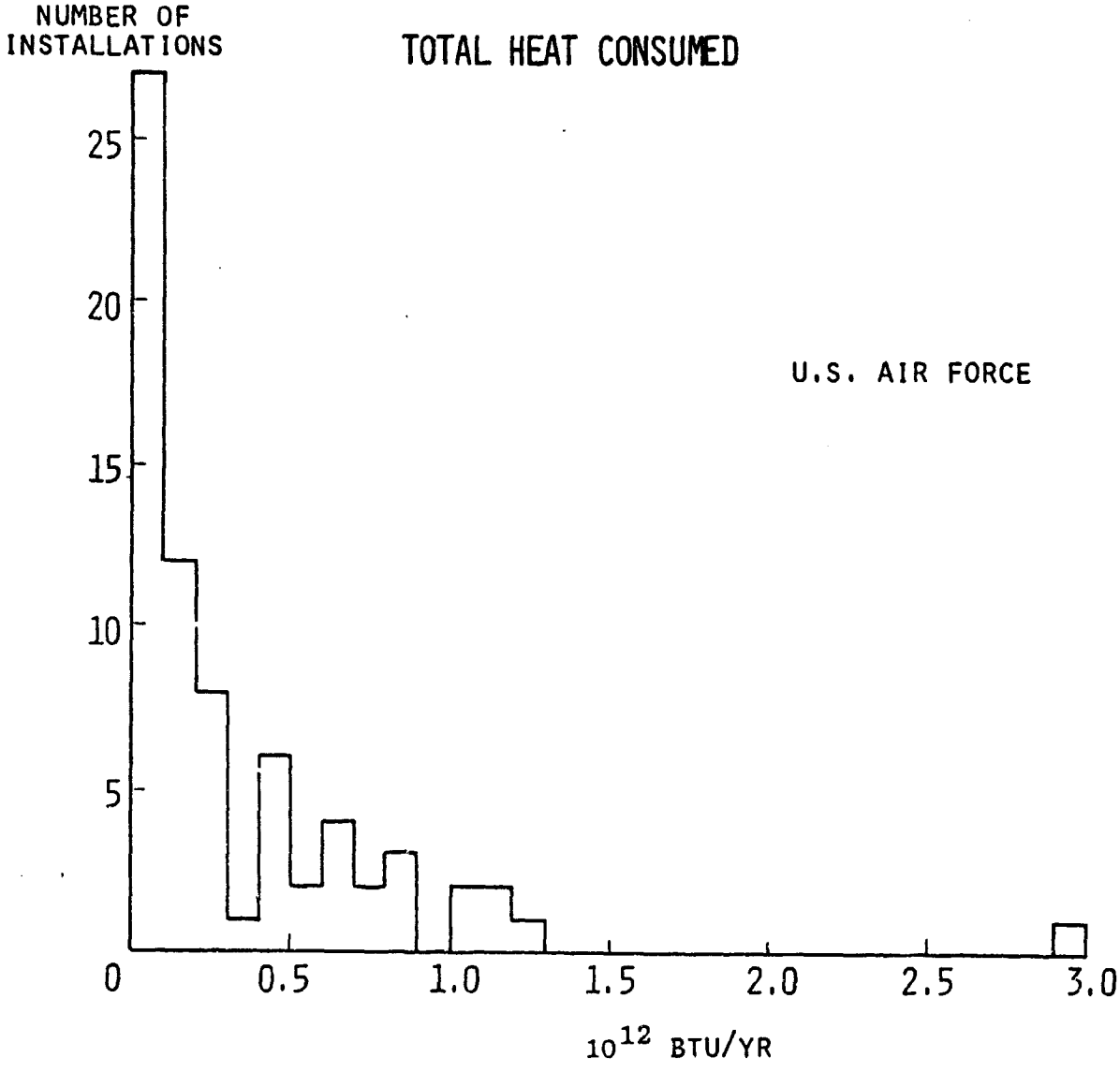


NOTE: DOES NOT INCLUDE THIRTY-FOUR INSTALLATIONS THAT REPORTED LESS THAN 100 MW-HR/YR GENERATED.

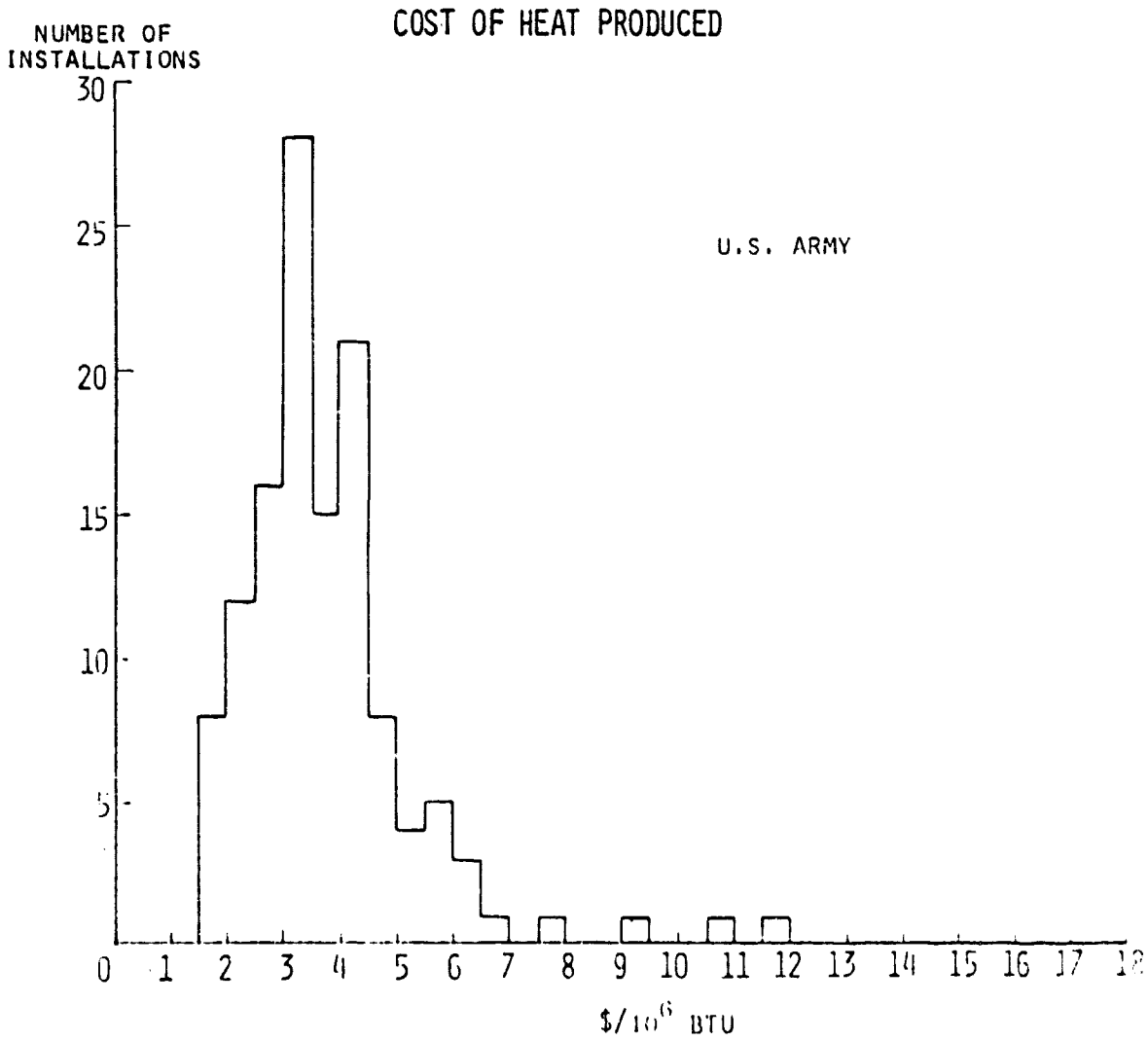
TOTAL ELECTRICITY CONSUMED




NUMBER OF INSTALLATIONS
COST OF PURCHASED ELECTRICITY
U.S. NAVY
30
25
20
15
10
5
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
MILS/KW-HR

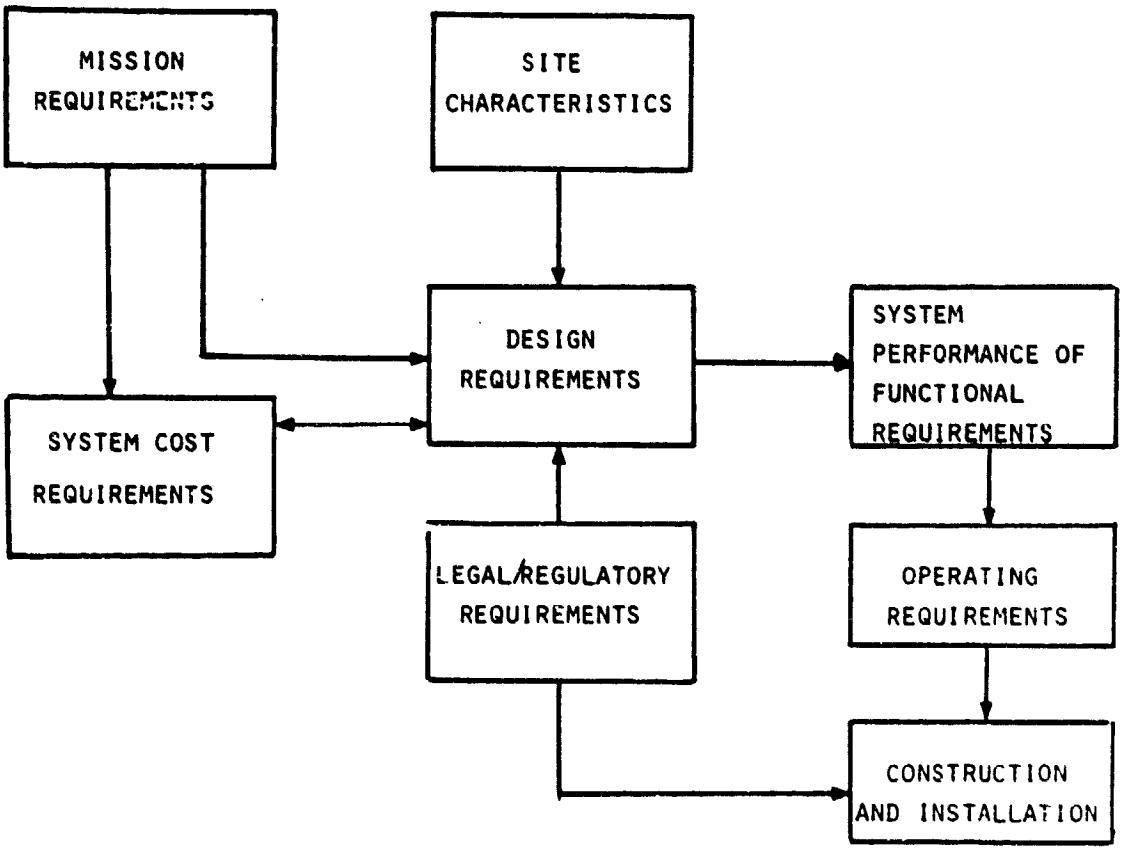


NOTE: DOES NOT INCLUDE NINETEEN INSTALLATIONS THAT REPORTED LESS THAN 0.03×10^{12} BTU/YR CONSUMED.


COST OF HEAT PRODUCED
NUMBER OF INSTALLATIONS
30
25
20
15
10
5
U.S. ARMY
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
$/10^6 BTU

SOLAR THERMAL ELECTRIC PLANT REQUIREMENTS DEFINITION

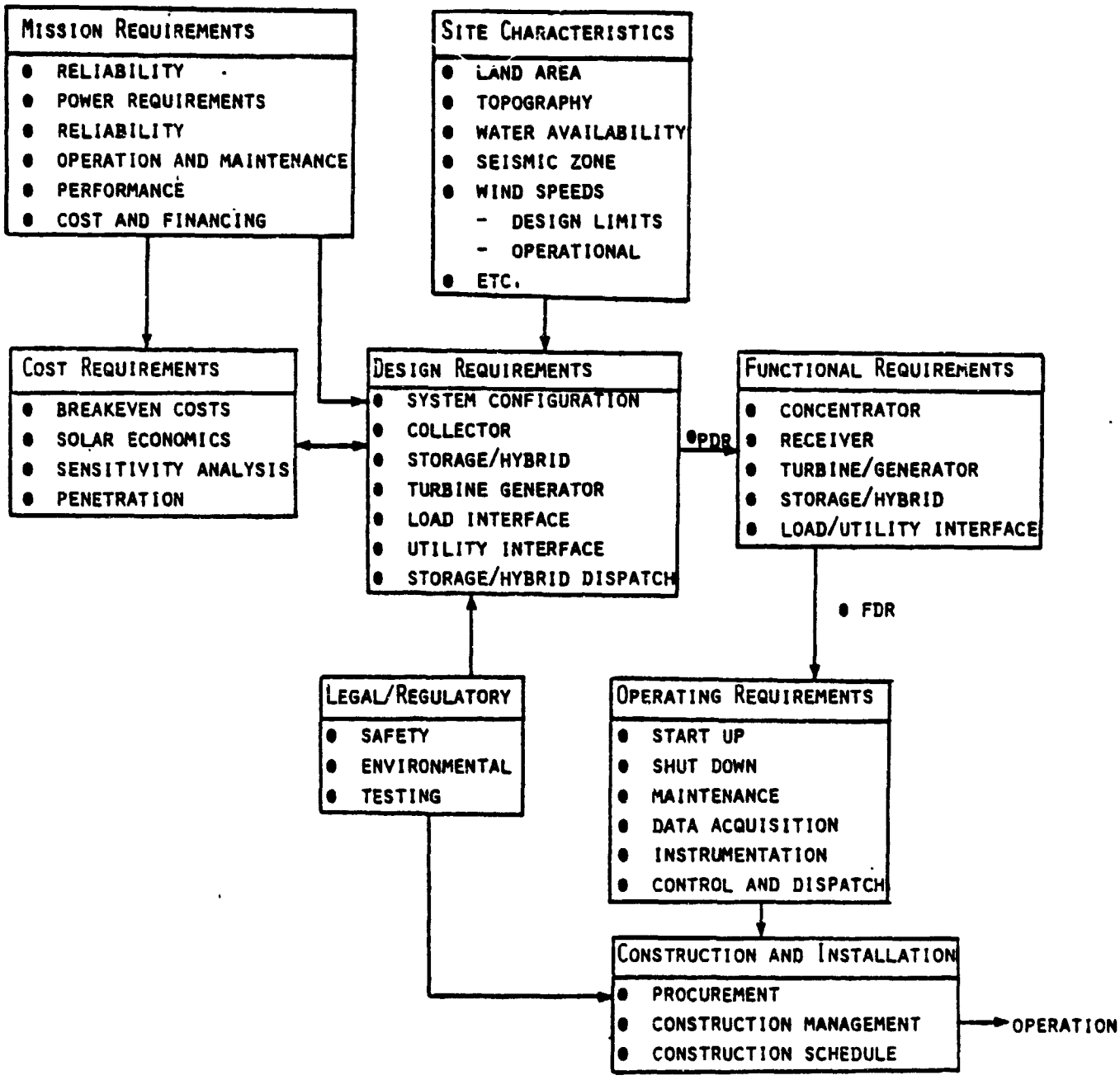
OVERVIEW OF REQUIREMENTS DEFINITION



KEY CONCEPTUAL DESIGN PARAMETERS

- PREFERRED SYSTEM CONFIGURATIONS
- COLLECTOR AREA
- STORAGE
- TURBINE GENERATOR CAPACITY
- HYBRID CAPACITIES
- BALANCE OF PLANT
- LOAD INTERFACE
- UTILITY INTERFACE
- STORAGE/HYBRID OPERATING STRATEGY
  - SUN FOLLOWING
  - TRANSIENT BUFFERING
  - LEVEL OUTPUT
  - STARTUP
  - PEAK SHIFTING

KEY ELEMENTS OF REQUIREMENTS DEFINITION



The following questions were directed to and answered by Dr. Yudi Gupta, SAI:

Q. "The Department of Planning and Economic Development for the State of Hawaii is conducting a program to study the energy picture of the next 25 years. The largest problem that has been encountered is that of obtaining data on cost, performance, etc. Is the information which has been presented here available for distribution, even though it is in preliminary form?"

A. "A data base summary report has been completed and has been submitted to JPL. After review and modification, this report should be available from their office."

Q. "What criteria were used for selection of the 'attractive' industries?"

A. "Among those considered were profitability, (return on investment), market size, land availability and load shape."

REQUIREMENTS FOR ISOLATED POWER SYSTEMS

COMMUNICATIONS SITES

APPLICATIONS
&
REQUIREMENTS

Eugene Phillip
Defense Communications Agency

Slide 1

MilHdbk 411 establishes performance requirements and configurations for Power Systems supporting DCS stations.

Under reliability, the handbook states in effect that the primary power source and distribution system should be engineered and designed to provide optimum reliability at the lowest overall cost, considering initial installation, maintenance, and operation. The amount and class of auxiliary power required at facilities is determined by the degree of reliability dictated by strategic and operational considerations. The handbook makes the following statement under availability. The primary power supply, auxiliary power supply, and distribution system shall be engineered so as to provide 99.99% availability (exclusive of scheduled outages) to the technical load bus and not in excess of 53 minutes total outage time during any one year.

DCA Circular 350-125-1 establishes planning principles shown on this slide.

1. POWER SYSTEM PERFORMANCE REQUIREMENTS

2. POWER SYSTEM CONFIGURATIONS AND WEAKNESSES

3. POWER DEMAND RANGES FOR DCS SITES

4. FUEL DELIVERY PROBLEMS

5. NEED FOR COGENERATED HEAT

6. OPERATIONAL CONSTRAINTS

Slide 2

The foregoing constitutes the essence of DCA guidance on Power Systems for the DCS. Now I'll discuss Power System Configurations illustrating some of the ways to provide power system availability meeting DCA's 99.99% requirement.

Power availability to the load can be increased by providing a second utility source.

PLANNING PRINCIPLES

A. THE REQUIREMENT FOR POWER IMPROVEMENT PROJECTS WILL BE BASED ON:

(1) UNACCEPTABLE AVAILABILITY, CONSIDERING OVERALL SYSTEM IMPACT;

(2) REPORTED DEFICIENCIES;

(3) OBSOLETE EQUIPMENT AND PARTS;

(4) UNSAFE OPERATING CONDITIONS; OR

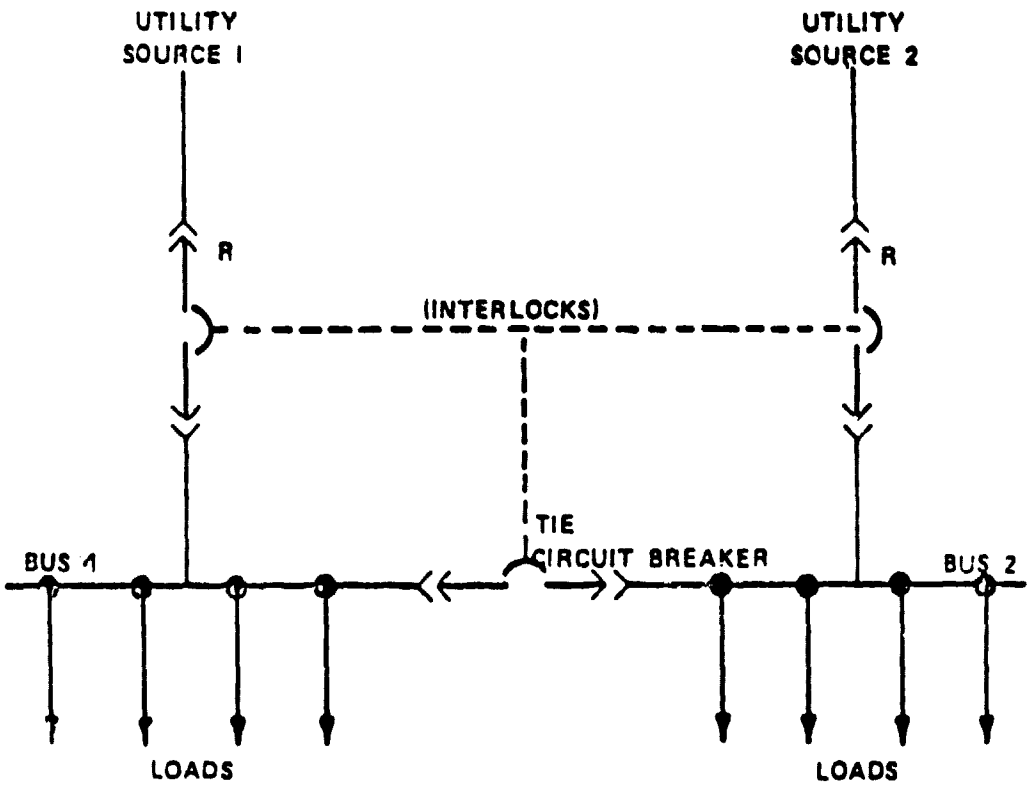
(5) INCREASED MISSION CAPABILITY.

B. POWER IMPROVEMENT FOR THE SOLE PURPOSE OF FRACTIONAL INCREASE IN POWER AVAILABILITY WILL BE AVOIDED.

Slide 3

This is not usually viable, For the second source is seldom available and an outage to one half the load occurs in switching from source to source.

Two utility sources combined with an engine generator set to provide varying degrees of emergency power is shown here.

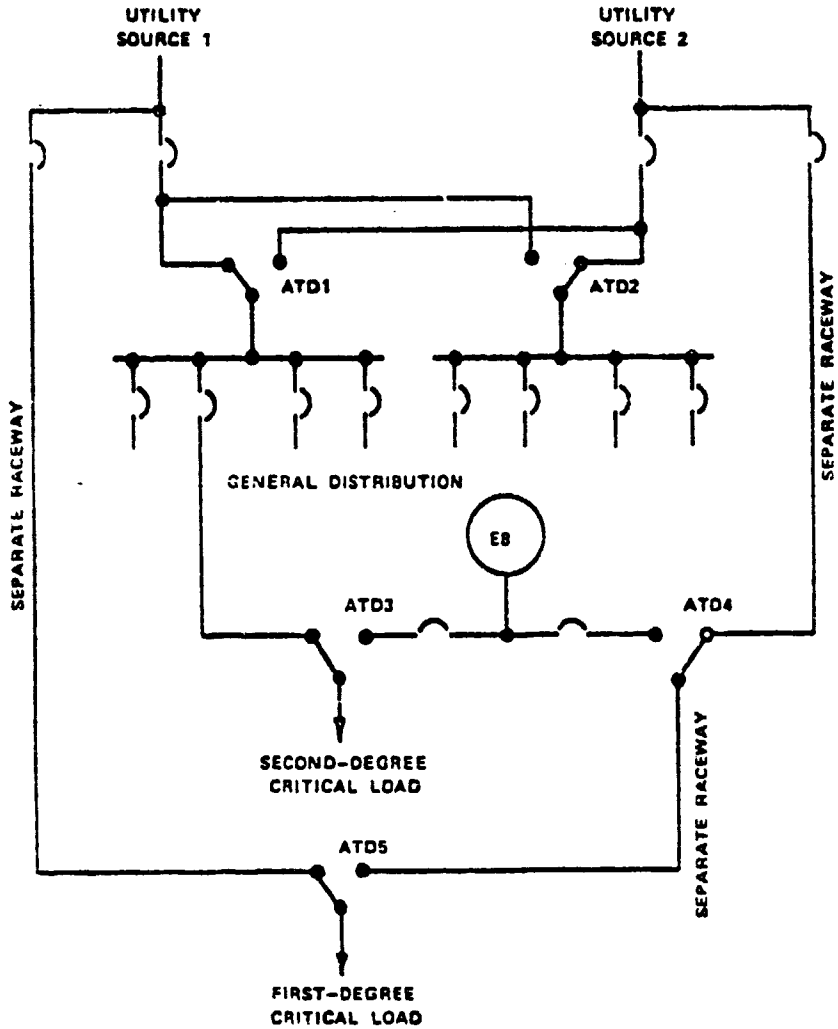


TWO-UTILITY-SOURCE SYSTEM WHERE ANY
TWO CIRCUIT BREAKERS CAN BE CLOSED

Slide 4

On-site standby generators would always be provided to DCS stations for immediate recovery from outages and as protection against catastrophic type commercial power failures resulting from civil strife, tornadoes or network blackouts.

There is yet another factor besides availability to be considered and that is the impact of computers on Power System, or perhaps I should say the impact of raw power on computers.



TWO UTILITY SOURCES COMBINED WITH AN ENGINE GENERATOR SET TO PROVIDE VARYING DEGREES OF EMERGENCY POWER

Slide 5

As indicated on this slide of typical line voltage tolerances of computers, a reduction in voltage below 90% of normal for 30 cycles constitutes an outage; a reduction to 75% of normal for only a fraction of a cycle constitutes an outage. Significant equipment degradation and data loss can result without even approaching overall availability requirements.

The effects of power supply disturbances must be reduced to acceptable levels or eliminated. Possibilities include the following:

(1) Modify electronic and computer equipment to be impervious to power disturbances and discontinuities.

(a) Design for DC input

(b) Provide circuits with greater tolerance for disturbances and discontinuities

(c) Include energy storage circuits in power supplies to provide ride-thru capability.

Suggested design parameters may be:

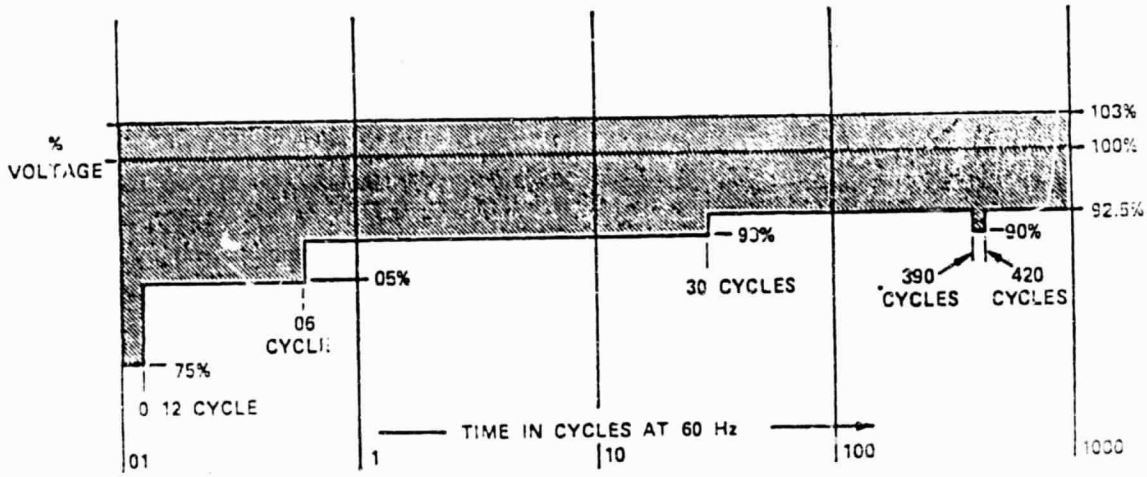
* Voltage dips to 60% or rated for a 5Hz period
* Pulse transients of 500 volts peak to peak up to 1/2Hz duration
* Frequency deviation of 1/2Hz.

(2) Interposing a motor-generator power conditioner or an uninterruptible power supply system between the prime source and the computer. Either will function as a buffer to transients.

Although users may exert some influence upon communications-electronics equipment design through their procurement specification, in the past the only option available to communications systems users is the power conditioning option.

Currently, static UPS procurement costs are $1400/KW. These systems are costly to operate and maintain, consuming 20% of their output in internal losses, requiring an air conditioned space for maximum reliability and skilled technicians to repair.

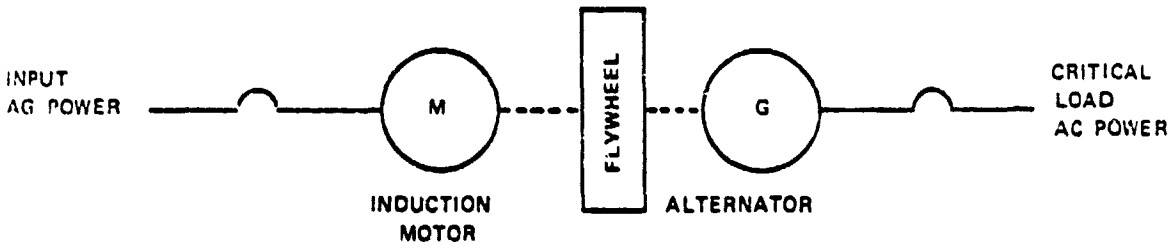
These next 5 slides illustrate various UPS configurations.



COMPOSITE ALTERNATING–CURRENT LINE VOLTAGE TOLERANCES OF COMPUTER MAIN FRAMES OF SEVEN DOMESTIC MANUFACTURERS

Slide 6

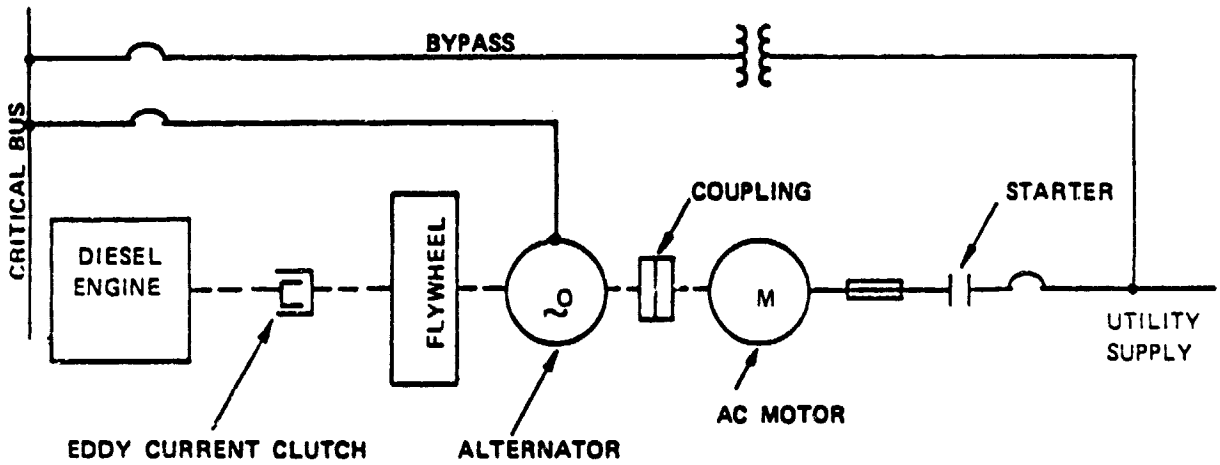
A motor generator with flywheel provides a minimum of 300MS ride thru. Reliability is limited by an extremely heavy and high speed flywheel.



SIMPLE INERTIA–DRIVEN "RIDE–THROUGH" SYSTEM

Slide 7

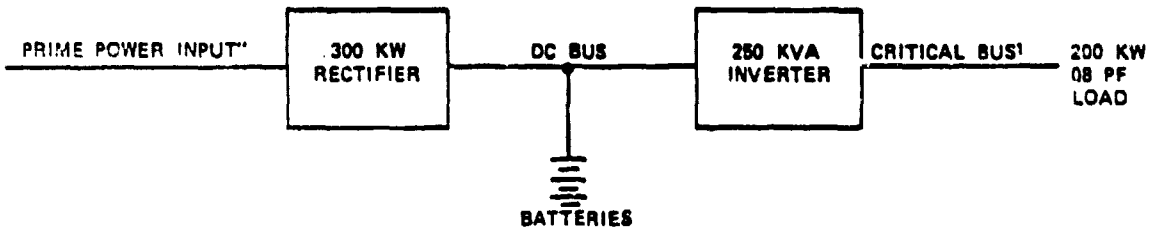
This system is usable where critical loads can tolerate the 1.5Hz frequency drop during transition to diesel drive.



ROTATING FLYWHEEL NO-BREAK SYSTEM

Slide 8

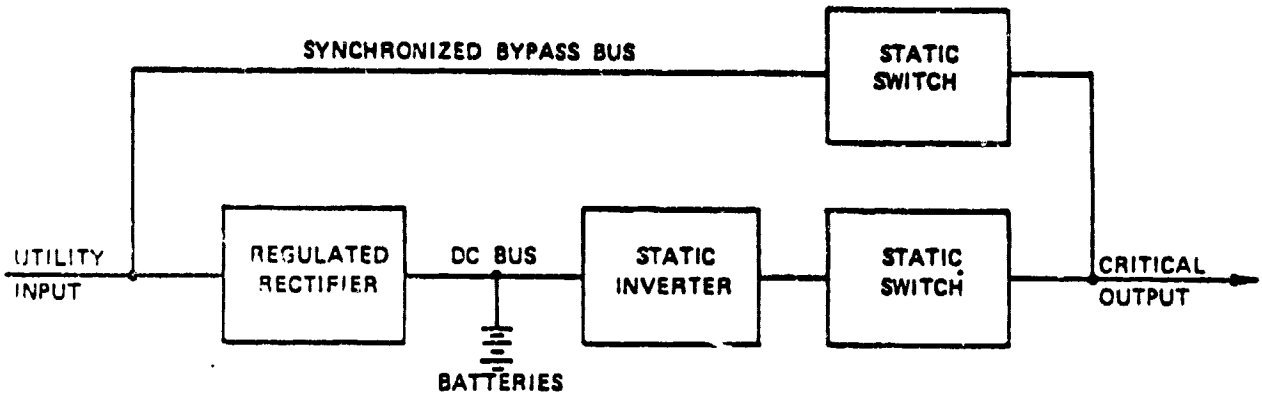
Manufacturers claim an Mean Time Between Failure (MTBF) of 20,000 hours for the non-redundant status UPS.



NONREDUNDANT UNINTERRUPTIBLE POWER SUPPLY SYSTEM

Slide 9

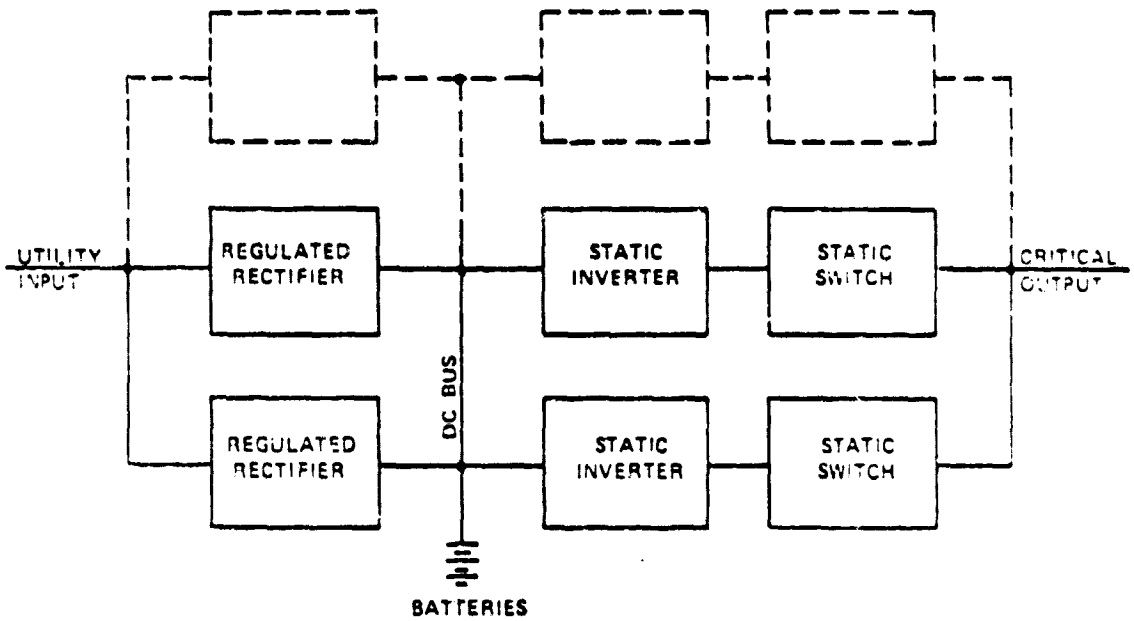
According to the IEEE STD 446, the parallel redundant system is two to four times more reliable than a non-redundant system; but the equipment cost is double. However, this concept allows for maintenance of one unit while the other carries the load. Normal operation would consist of both units sharing the load. When one fails, only a 50% load transfer would be experienced. The Navy has had success with a more efficient variation of this scheme. When one unit operates fully loaded, the other remains off. If the loaded unit fails, the load transfers to the synchronized bypass until the spare unit is turned on. This provides greater energy efficiency but a 100% load transfer is necessary.



UNINTERRUPTIBLE POWER SUPPLY SYSTEM WITH STATIC BYPASS

Slide 10

The static bypass switch adds only about 20% to the cost of a non-redundant system but is 8 to 10 times more reliable. Army Communications Command favors this system as being most cost effective. Particular communications subsystem requirements should be considered in making the final design selection.

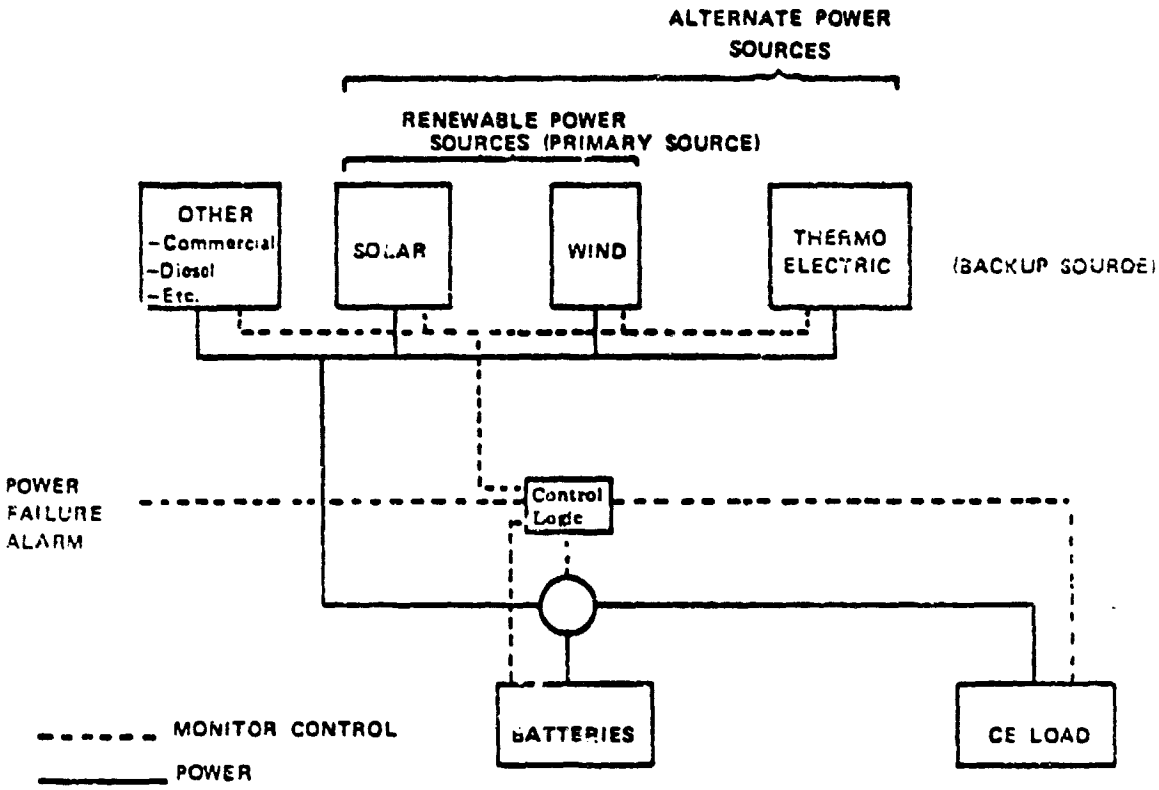


REDUNDANT UNINTERRUPTIBLE POWER SUPPLY SYSTEM

Slide 11

DCA through the Defense Communications Engineering Center at Reston, Virginia, has recently tasked the Army to determine the feasibility of integrating multiple sources of power into a consolidated alternate power system for unattended communication facilities. The power sources would consist of photovoltaic cells, thermoelectric generators, and batteries. Most important is the essential control logic which will perform the switching as their capability to provide power varies. This slide exemplifies a basic concept which may be used at an unattended microwave repeater location.

DCS ALTERNATE UNATTENDED POWER SYSTEM (DAUPS)



- 8 HOUR BACKUP POWER IN THE EVENT OF TOTAL FAILURE

- HIGHLY SENSITIVE TO VARIATIONS IN VOLTAGE AND FREQUENCY (MICROPROCESSOR)
- .5 KW (APPROX) CONSTANT LOAD

Slide 12

Objectives are shown on this slide.

PROJECT OBJECTIVES. SPECIFIC OBJECTIVES OF THIS PROJECT ARE TO:

A. VERIFY THE FEASIBILITY OF USING RENEWABLE SOURCES OF POWER (SOLAR AND WIND) AS A PRIMARY ENERGY SOURCE FOR MILITARY COMMUNICATIONS APPLICATIONS.

B. VERIFY THE CAPABILITY OF A PROTOTYPE DAUPS TO OPERATE UNATTENDED FOR LONG PERIODS OF TIME (60–90 DAYS).

C. CONDUCT A GOVERNMENT/INDUSTRY SURVEY AND TRADE-OFF ANALYSIS GEARED TO ENHANCE THE INITIAL DAUPS DESIGN AND TO GUIDE THE DESIGN OF SEVERAL EXPERIMENTAL MODELS FOR ACTUAL DEPLOYMENT AND USE IN AN OPERATIONAL ENVIRONMENT.

D. VERIFY THAT COMMERCIALLY AVAILABLE ELECTRIC POWER GENERATING AND CONTROL EQUIPMENT CAN BE ECONOMICALLY AND EFFICIENTLY CONFIGURED TO SATISFY SELECTED MILITARY COMMUNICATION APPLICATIONS.

Slide 13

Technical management.

Because of multiple missions, configurations are continually improved, modified, consolidated, and dispersed. Additionally, each of the military departments have slightly different methods of operating, maintaining, procuring, and installing power systems to support DCS loads.

The following figures are presented with these variables in mind. A microwave site as shown would consist of approximately 30KW of load at 48 volts DC. Repeater sites may be as low as 1KW at 48 volts DC.

TECHNICAL MANAGEMENT

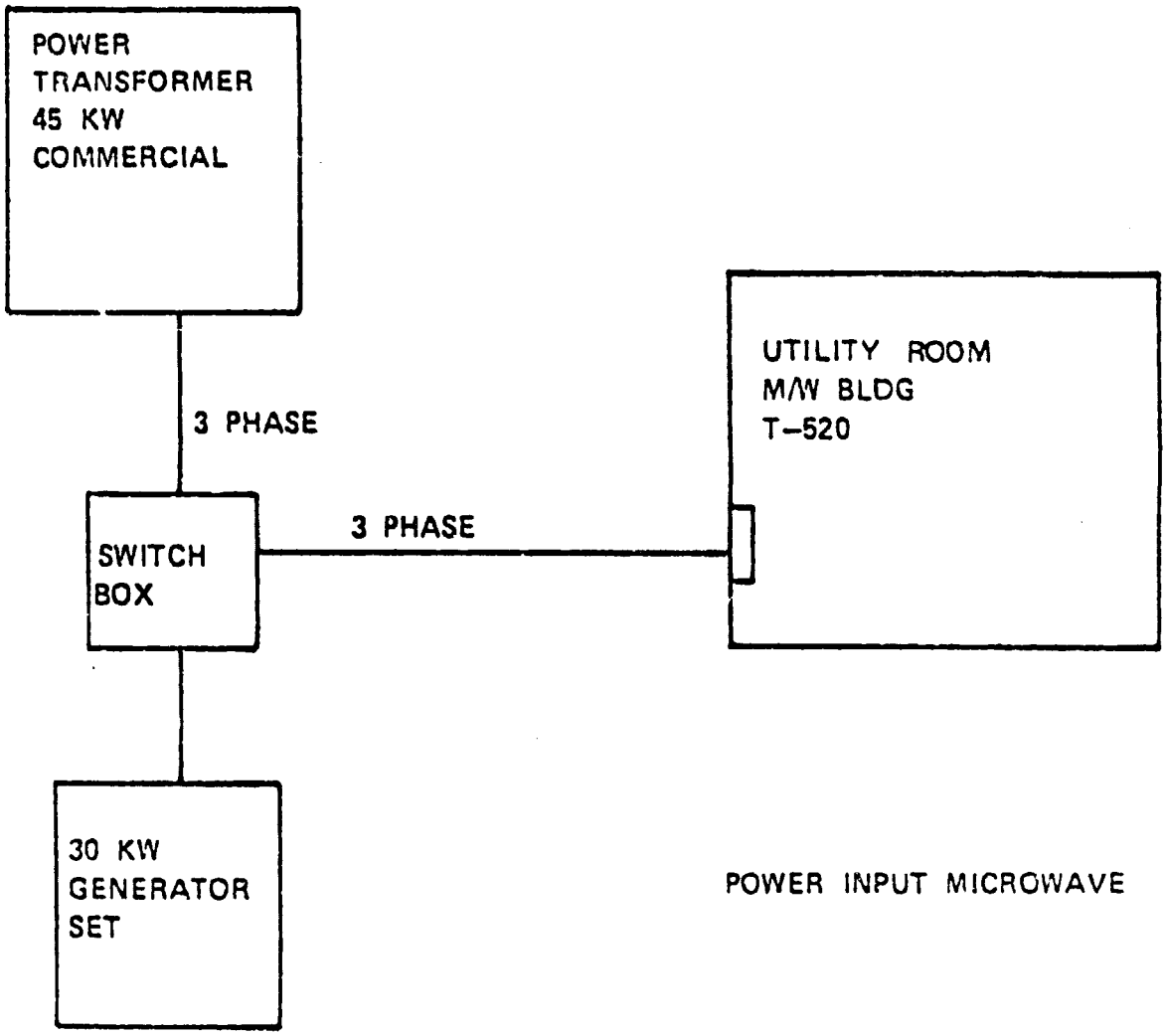
- DEFENSE COMMUNICATIONS ENGINEERING CENTER. THE DEFENSE COMMUNICATIONS ENGINEERING CENTER (DCEC) IS THE PROPONENT OF THIS PROJECT.

- HQ DEPARTMENT OF ARMY (DAMA-CM). HEADQUARTERS DEPARTMENT OF ARMY (DAMA-CM) HAS ASSIGNED COMBAT DEVELOPER AND MATERIAL DEVELOPER RESPONSIBILITIES TO HQUSACC AND HQUSA DARCOM, RESPECTIVELY.

- HQ US ARMY COMMUNICATIONS COMMAND (CC-OPS-P). HQUSACC (CC-OPS-P) HAS THE RESPONSIBILITY TO OPERATE AS THE COMBAT DEVELOPER ON THIS PROJECT. ALL APPROVED ACTIONS WILL BE ACCOMPLISHED THROUGH AND BY THIS OFFICE.

- HQ US ARMY COMMUNICATIONS-ELECTRONICS ENGINEERING INSTALLATION AGENCY (CCC-SEO). HQUSACEEIA (CCC-SEO) HAS THE ASSIGNED RESPONSIBILITY TO ESTABLISH THE DETAILED TECHNICAL OBJECTIVES AND PRODUCTS FOR THIS PROJECT ADHERING TO DCEC GUIDELINES AND REPORT TO HQUSACC ON THE ACCEPTABILITY OF SYSTEMS ENGINEERING APPROACH TAKEN AND RESULTS OBTAINED IN MEETING PROJECT OBJECTIVES.

- US ARMY COMMUNICATIONS SYSTEMS AGENCY (CCM-RO). HQUSACSA (CCM-RD) HAS THE RESPONSIBILITY TO PERFORM ALL PROJECT MANAGEMENT FUNCTIONS FOR THIS PROJECT IN LINE WITH TASKING FROM HQUSACC.



POWER INPUT MICROWAVE

MAJOR REQUIREMENTS ARE:

1. UNATTENDED OPERATIONS FOR 60–90 DAYS.

2. MAINTAIN A HIGH QUALITY CONSTANT POWER OUTPUT.

3. 30% OF POWER TO BE PROVIDED FROM A RENEWABLE SOURCE (WIND OR SOLAR).

DESIGN REQUIREMENTS ARE:

POWER OUTPUT: .5 KW CONTINUOUS (ULTIMATELY 4KW ASSY'S)

VOLTAGE: 110VAC/48VDC

VOLTAGE REGULATION: ± 1% NO LOAD TO FULL LOAD, .8 TO UNITY POWER FACTOR.

VOLTAGE RECOVERY: FOR SUDDEN APPLICATION OF FULL LOAD THE OUTPUT VOLTAGE SHALL NOT DEVIATE FROM NORMAL BY MORE THAN 10% AND SHALL RETURN TO WITHIN ± 1% OF NORMAL WITHIN 20 MILLISECONDS.

FREQUENCY REGULATION: ± .5% (½%)

HARMONIC DISTORTION: LESS THAN 5%.

BATTERY STORAGE: 8 HOURS UNDER CONTINUOUS LOAD.

ENERGY SOURCE: 30% FROM RENEWABLE SOURCE (SOLAR & WIND)

UNATTENDED OPERATION: 90 DAYS WITHOUT MAINTENANCE OR REFUELING.

DC SYSTEM SHALL DELIVER TRANSIENT FREE OUTPUT VOLTAGE WHICH SHALL NOT VARY MORE THAN [illegible] FROM NORMAL AND WITH RIPPLE DUE TO AC-DC CONVERSION LIMITED TO .02% OR LESS.

DC TO DC VOLTAGE REGULATOR NOISE LIMITED TO 32 DBRN, AND OR TRANSIENT VOLTAGE SUPPRESSION ARE ACCEPTABLE.

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OF POOR QUALITY

GENERAL ALLOCATION OF FUNDS SHOULD BE:

A. PROGRAM MANAGEMENT (ESTIMATED PROJECT AND TECHNICAL INCLUDING DESIGN)		$25K
B. ACQUISITION OF COMPONENTS		
(1) GENERATORS	30K	
(2) CONTROL LOGIC	30K	
(3) BATTERIES	5K	
	65K	65K
C. FABRICATION		10K
D. TEST & EVALUATION		25K
TRADE-OFF ANALYSIS		25K
		$150K

TRADE OFF ANALYSIS SHOULD:

A. PROVIDE GLOBAL INFORMATION ON EXPECTED SOLAR AND WIND POWER INFORMATION (MICROCLIMATIC CONDITIONS).

B. PROVIDE INSTRUCTION ON OPTIMIZING CONFIGURATION TO DIFFERENT MICROCLIMATIC CONDITIONS.

C. IDENTIFY OTHER PROMISING GENERATOR EQUIPMENT WHICH COULD BE USED IN LIEU OF THE PROTOTYPE GENERATOR EQUIPMENT SELECTED.

D. PROVIDE INSTRUCTION ON CONFIGURING THE DAUP FOR DEPLOYMENT TO A GIVEN GEOGRAPHICAL SITE.

TRADE OFF ANALYSIS AND TEST RESULTS SHOULD PROVIDE:

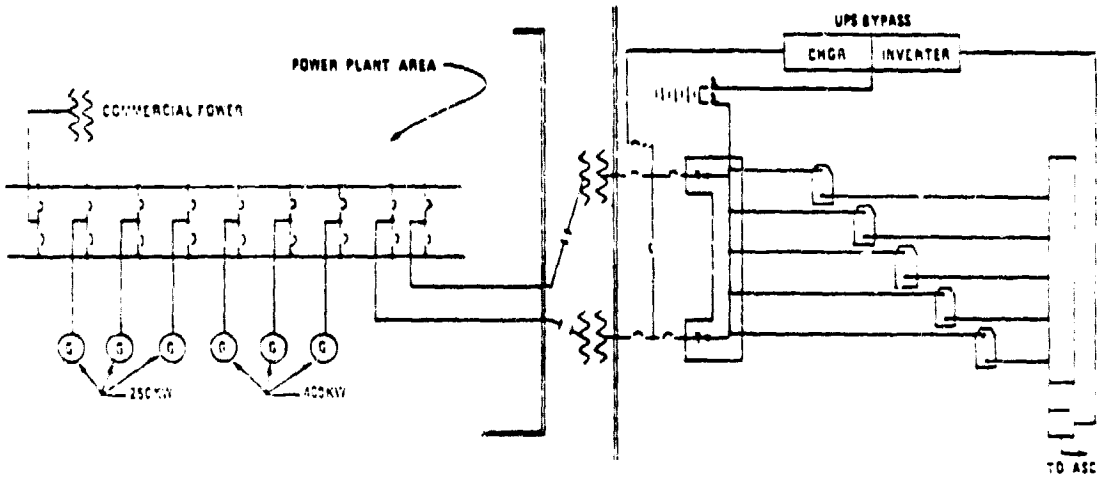
(1) RECOMMENDED CONFIGURATIONS OF THE DAUPS TO BE DEPLOYED TO DIFFERENT GEOGRAPHICAL LOCATIONS AROUND THE WORLD.

(2) METHODS TO ADJUST POWER OUTPUTS FOR DIFFERENT REQUIREMENTS.

(3) METHODS TO OPTIMIZE UNIT EFFICIENCY CONSIDERING MOVES AND MICROCLIMATIC CONDITIONS.

Slide 20

An AUTODIN switch as shown may range from 105 to 160 KW, AC. The present overseas AUTODIN switches use commercially available prime power with a number of standby diesel generators. Five rotating motor-generator sets provide the power continuity to the critical load. A solid state UPS bypass system was installed in 1974 to allow maintenance of the rotating M-G sets.


UPS BYPASS
CHGR
INVERTER
POWER PLANT AREA
COMMERCIAL POWER
250KW
400KW
TO ASC

Slide 21

This slide summarizes the typical load information.

C-3

TYPICAL DCS LOADS

MICROWAVE	1 KW (REPEATER) - 30 KW @ 48V DC
AUTODIN SWITCH	105 - 160 KW AC
AUTOVON SWITCH	17 KW @ 48V DC
TROPO	60 - 100 KW AC
SATELLITE EARTH TERMINAL	100 - 200 KW AC
TECHNICAL CONTROL	1 - 10 KW DC
COMM CENTERS	(NON-DCS)
AMME SWITCHES	60 - 90 KW AC
REMOTE TERMINALS	5 -12 KW AC

NUMBER OF SITES

DCS	TOTAL 608 (AF-284, ARMY-218, NAVY-106) EUROPE 47%, PACIFIC 37%, WESTERN HEMISPHERE 16%
NON-DCS (ARMY)	AMME SWITCHES 15-20 REMOTE TERMINALS 150-200

Slide 22

Now I will speak for the civil engineer who has more than power to worry about. Heating, cooling, and dehumidification are essential to continued operation of communications facilities as electrical power itself. But these environmental control systems require power to perform their functions and must not be neglected in any power system design. In most cases environmental control is not critical technical load requiring UPS, but if a standby power source is not on the line quickly, the communication equipment may go down for lack of cooling. Personnel comfort may not have a direct effect on communication operation, but overall efficiency is degraded in the long run if people are uncomfortable. Ventilation of battery rooms might require a few watts of power, but if it is interrupted for an extended period of time, a disastrous explosion may result. All these problems must be considered in addition to the basic communication/electronics load.

One operational constraint which may not influence non-military communications systems is survivability. The DCS has a wartime role which must take into account at least partial operation under the affects of nuclear weapons, chemical and biological warfare, electronic warfare, conventional weapons, sabotage, and other unauthorized entry.

In conclusion, the Defense Communications System has a full range of possible applications for alternate power systems, but with some special requirements such as high availability and survivability. The most practical application at this time is unattended microwave repeater sites. DCEC has tasked the Army to develop an integrated system for such an application, consisting of photovoltaic cells, thermoelectric generators and batteries. The success of this should open the door to other larger scale applications in the DCS.

OTHER CONSIDERATIONS

1. ENVIRONMENTAL CONTROL

2. SURVIVABILITY

The following question was directed to and answered by Mr. Eugene Phillip, DCA:

Q. "Has the possibility of radioisotopes been explored for uninterrupted power systems?"

A. "The Army has studied this, but for various reasons designs have not been changed to include this possibility."

Comment

"Conceptually, it does not appear that parabolic dish units would be suitable for unattended applications due to the possible maintenance necessary to the tracking mechanism, and due to possible adverse weather conditions. On the other hand, the Brayton or combined cycle Stirling may be quite dependable for such operations as replacements to less efficient diesels. On larger applications, the point focusing technology may serve more appropriately since they could also meet space conditioning requirements."

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ISLAND APPLICATIONS OF CENTRAL RECEIVER SOLAR POWER SYSTEMS

Eugene M. Grabbe
Department of Planning and Economic Development
State of Hawaii

I am delighted to be with you, and as a representative of the Hawaii State government, to share the island environment perspective with you. Solar thermal power can play an important role in island energy supply, especially if the plant is designed to match the local environment, power requirements and social expectations. The State of Hawaii is actively involved in all facets of alternate energy research, with programs aimed at developing our ample insolation wind, biomass, geothermal, ocean thermal and hydroelectric resources as rapidly as is feasible. Hawaii's Governor, George R. Ariyoshi, has set a goal of energy self-sufficiency, and all other counties of the State are developing individual energy self-sufficiency programs. We have already begun seriously considering solar thermal electric power. In response to a recent U.S. Department of Energy proposal request, a ten-megawatt solar repowering system has been proposed for the Island of Kauai. This would be a cooperative project of Kauai Electric Co., the University of Hawaii Natural Energy Institute, and Bechtel Power Corporation. In addition, we are eagerly awaiting DOE's one-megawatt solar thermal power plant Request for Proposal. Molokai Electric, Hawaii's smallest utility, which has an aggressive alternate energy program, expects to respond to that program.

Hawaii works closely on energy and other matters with the other U.S. Pacific Islands. We have cooperated in solar planning with Guam, American Samoa, the Commonwealth of the Northern Marianas, and the Trust Territory of the Pacific Islands. The Trust Territory, as you know, has recently reorganized, and is now the Federated States of Micronesia and two quasi-independent island groups. So, my experience with the Pacific Islands ranges from large, mountainous, heavily-populated islands, such as Hawaii's

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Oahu, to small, sparsely-settled Micronesian atolls. Much of the information relating to this wide range of islands is applicable to other U.S. islands, such as Puerto Rico and the Virgin Islands.

The major thing all the U.S. Pacific Islands have in common is a high dependency on imported oil. We have no indigenous fossil fuel resources, either petroleum, natural gas, or coal. Hawaii is over 90 percent dependent on oil for energy; the other U.S. Pacific Islands are completely dependent on oil. Although some crude oil and petroleum products are shipped in from the U.S. Mainland, most of the crude oil imports for our two refineries are foreign. Thus, the Islands are more susceptible to dislocations in the international oil market than any Mainland State.

Furthermore, each island's electric grid is independent. Even in heavily-populated and technically-advanced Hawaii, there are no inter-island utility entities. The necessary transmission technologies have not yet been shown to be economic. Hawaii has considered submarine cables, but none have ever been laid at the great depths which occur between the Hawaiian Islands. Petroleum must, therefore, not only be imported into the State or territory, but shipped from island to island as well.

As you can imagine, our energy costs are highly dependent on the price of oil. In Hawaii, we have among the highest electricity rates in the nation, ranging from over five cents per kilowatt-hour for the first 100 kilowatt-hours per month on Oahu, the most densely-populated island, to nine cents per kilowatt-hour on the Island of Molokai. A fuel adjustment clause allows changes in customer rates based on changes in fuel price, so rates can change from one billing period to the next.

It is, however, a different situation in the other U.S. Pacific Islands. In Micronesia and the Northern Marianas, U.S. government subsidies keep the customer's electricity cost at approximately three cents per kilowatt-hour, although it costs over seven cents per kilowatt-hour to generate. This policy was adopted to encourage economic development, and some island governments have considered changing it to more accurately reflect the cost of power generation. American Samoan electricity customers pay approximately seven cents per kilowatt-hour, and Guam's customers pay

approximately five cents per kilowatt-hour. All these figures are for 1977.

All of the U.S. Pacific Islands have a deep interest in reducing their dependence on oil imports, and increasing their use of indigenous, essentially inexhaustible resources such as solar radiation. These islands have the highest annual average insolation rate in the nation. Hawaii averages 1,915 Btu per square foot annually, with higher winter incidence than any Mainland State. The State's insolation resource is being measured and mapped by the University of Hawaii, and for some sites long-term insolation data have already been gathered by the sugar industry. The other Pacific Islands have not been extensively surveyed for their insolation resource, but since they lie even closer to the equator than Hawaii does, and since their terrain is less mountainous, and fewer clouds are generated, it is safe to say that their insolation equals or exceeds Hawaii's. These tropical sites in the equatorial zone have little difference between the amount of sunlight available at the winter solstice and at midsummer.

You can see that the Pacific Islands share two important characteristics: an ample solar radiation resource, and a great need to reduce oil imports. Both of these factors will encourage the use of solar thermal power. However, there is another shared factor which will limit solar thermal development: lack of land area.

By Mainland standards, Pacific Islands are small. The State of Hawaii encompasses 6,425 square miles of land, with the smallest of the populated major islands, Lanai, being approximately 140 square miles. This would be ample for solar power generation, if that were the only use for the land. Being so limited in land area, however, real estate is one of Hawaii's major commodities. With the demands of a growing population, including more housing, roads, recreation areas, and agriculture, it will be difficult and expensive to obtain large contiguous areas for solar thermal power development. This does not by any means rule out the solar thermal power option; it just means that sites will have to be carefully searched for and selected. The other Pacific Islands are even more limited in land space, but have not yet experienced the same degree of pressure on land use due to population.

So, availability of land is a very important limiting factor. The land situation and the lack of inter-island utility interplay tends to favor smaller solar power plants, sized and sited to meet local needs. What sizes might be best?

Hawaii is by far the largest power consumer of the U.S. Pacific Islands. In turn, the Island of Oahu, with over 80 percent of the State's population, is the largest energy consumer. Oahu now has an installed capacity of 1,200 megawatts. Compare this with our smallest utility on Molokai, with a capacity of only eight megawatts.

The other U.S. Pacific Islands have even smaller demands. Guam is the largest power producer, with a capacity of approximately 300 megawatts. Saipan has a capacity of 40 megawatts, and some of the smaller islands have capacities below one megawatt--ranging from 40 to 600 kilowatts. Almost all of the electricity in the Pacific Island territories is generated by deisel equipment, much of it antiquated.

This is not to say that the Pacific Islands have all the power they want or need. In most cases, electricity is only available in the population centers, leaving the villages without power. Often, the generating capacity is sufficient to support electric lights and communication devices, but not enough for refrigeration, which has serious effects on the islands' economy and the health of their people. Recognizing the need for more power to support a more robust economy, and yet realizing that dependence on petroleum imports for economic health can have devastating effects, most Pacific territories' governments are seeking ways to increase their energy self-sufficiency, utilizing solar and other indigenous energy alternatives.

There are many defense installations on both large and small Pacific islands where solar thermal electric installations may have applications. Such potential users have not been identified by the State; however, we maintain close liaison with key energy personnel in U.S. Defense organizations in Hawaii which are headquarters for many Pacific operations. The experience in civil systems will be applicable to military users.

It seems obvious from the generating capacities which we have just reviewed that the State of Hawaii, Guam, and perhaps a few of the large islands may be able to use megawatt-range solar thermal installations. The vast majority of the U.S. Pacific Islands, however, cannot support that size of a plant. Most islands will also be seeking a 24-hour power source, to allow the use of radios, refrigerators, and similar appliances. Either storage or backup generating capacity must be supplied to ensure this required reliability. For small remote islands with small population, the radio takes the place of the newspaper and the local people have come to depend on radio communication for information. This demand could be met by small solar thermal electric systems.

Another factor which must be considered when designing equipment for island environments is the corrosive quality of salt-laden air. In Hawaii, it has been shown that salt corrosion and fouling of reflective surfaces decreases almost geometrically with distance from the shoreline and elevation above sea level. Hawaii's many mountains help deflect the wind, and corrosion is not a serious problem inland. The Pacific atolls, however, have no mountain masses to isolate them from salty winds: the entire islets are, in effect, shoreline. Corrosion is a serious problem which will effect your choice of materials, and the design of the system. In Hawaii, we have already experienced the failure of a small, experimental wind turbine after only a few months of operation due to corrosion in the electrical system.

The system should also be designed for the social system in which it will be placed. Hawaii is, compared to most of the other U.S. Pacific Islands, sophisticated technically. We also have little difficulty obtaining specialized services or materials from the U.S. Mainland, if local resources are not adequate. Elsewhere in the Pacific, however, technical skills are very limited, and the transportation and communication expenses are significant. A system requiring complex, specialized operating and maintenance skills and procedures may be inappropriate for the remote Pacific Islands. What is needed is reliable, simple equipment, easy to understand and to maintain in an island environment.

Of course, insolation is not the Pacific's only alternate energy resource. Hawaii has a particularly strong and reliable wind resource, our steady tradewinds being enhanced by mountain masses. Other Pacific islands may also have suitable wind regimes, but they have not been as extensively measured as Hawaii's has. Furthermore, most Pacific Islands--Hawaii excluded--are susceptible to typhoon winds. Other energy alternatives include geothermal--for Hawaii at least; ocean thermal energy conversion--excellent surface ocean temperatures and nearshore deep cold water exists surrounding most Pacific Islands; hydroelectricity is limited by lack of land area and the permeability of tropical soil; and biomass--wastes from agriculture, livestock, and municipalities, as well as crops specially grown for energy.

Many of the smaller islands in the Pacific do not have an extensive biomass resource. Subsistence agriculture and fishing are major economic activities, and do not generate large quantities of wastes. Small, homestead-sized methane generators are occasionally used, however.

In Hawaii, on the other hand, biomass is an important resource. Bagasse, a sugarcane waste, already serves as fuel and provides seven percent of the State's current total energy supply. Trees, hay, pineapple waste, and other cane trash are all being considered as biomass energy resources.

The use of biomass such as wood chips, sugarcane and pineapple wastes and municipal trash can be used in Hawaii in place of petroleum for steam generating plants can supply the backup energy source for solar-thermal electricity. Since biomass products can be stored after harvest or "on the stump" and depend on photosynthesis for growth, such a system would be independent of petroleum.

Already, as I mentioned earlier, Hawaii and other States have responded to a Federal RFP for a solar thermal installation on top of an existing conventional power plant. The conventional fuels provide consistency and backup, but are not used when the sun is shining brightly.

We can supply this same concept to a biomass-burning power plant. Instead of piggybacking solar thermal and diesel, for example, piggyback

solar and wood chips or bagasse. You use each renewable resource to its best advantage then: solar when it is available, and biomass when the sun is not out. This is an extremely attractive idea in Hawaii, and is already being considered by one utility, Molokai Electric, in its long-range plans. It is equally applicable anywhere with sufficient biomass resources.

So, we've seen that Hawaii and the other U.S. Pacific Islands have perhaps the nation's best insolation resource. In addition, their high dependence on oil provides the best incentive for solar energy development. Because of the limitations of land and the absence of inter-island utility connections, small solar thermal units, sized to meet local needs are most appropriate. The island environment poses some design problems, especially to overcome salt corrosion. In areas rich in alternate energy resources, biomass or some other "stored" energy could back up a solar thermal plant.

I think you'll agree that the solar potential in the Pacific is great. I look forward to discussing this more with you in our workshop sessions. In closing I would like to acknowledge the assistance of Andrea Gill of my staff in the preparation of this presentation.

SOLAR THERMAL POWER SYSTEMS IN DEVELOPING COUNTRIES

Alan Poole
Office of Energy,
Agency for International Development

I have been asked to review the LDC power system in terms that can help define applications and requirements for point focusing solar thermal power plants. This is quite a challenge, because the range of electric power systems and associated generating subsystem choices in LDC's is as large and diverse as in the developed world. On the one hand we have integrated grids supplying rather large urban loads, such as in southern Brazil where resources, economics, and system size have combined to create the world's largest power generating station, Haipu Binacional. On the other hand, we have large populated areas with no grid and very little power generation.

It is in these more isolated rural areas, away from the grid, that I presume you are most interested. This is fortunate for three reasons(a) it makes my preparation easier because it is more limited in scope; (b) AID has shown virtually no interest in urban systems anyway; (c) what little market analysis of the kind likely to be of interest to you has been done only for rural areas. This situation is beginning to change. AID is, with immense reluctance, moving into urban/industrial energy systems. If programs are intelligently designed, we should have considerable new information within 4-5 years of the components of urban energy demand (over time) which is essential for either centralized or decentralized solar energy system design for urban areas.

Meanwhile, in rural areas there is now some momentum towards elucidating the microstructure of rural demand, though unfortunately our understanding is still not very deep. Until very recently AID and other donor programs to supply electricity to rural areas meant essentially one thing-establish a grid. This strategy was not very hospitable to careful analysis of specific priority applications to determine how little capacity

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could be installed, since the objective was to uncover as large a latent demand as possible in order to spread the heavy investment in subtransmission and distribution. As a consequence, cost benefit analysis consisted of a shotgun fired at a multiplicity of miscellaneous uses, many of which certainly did not immediately impact the productivity of the local economy.

This does not mean that these "nonproductive" uses are undesirable, and we anticipate that classical rural electrification will proceed. However, there is also an argument that given limited financial resources and the large number of settlements with virtually no power, it is both more equitable and more efficient economically to pinpoint "strategic" welfare or productivity enhancing loads throughout a country. In this case it is quite possible that even with a higher unit cost per delivered kwh more strategic loads can be supplied with a given rural electrification investment budget than with the classical approach. This kind of thinking seems to be gaining favor with time, and it is, of course, good news for those interested in technologies adapted to decentralized applications. This approach, however, requires that we have a clearer idea of just what these loads and their specifications are. It also puts on pressure to develop technologies which are better adapted to rural requirements than the current generation of diesel generating sets.

Some loads have been identified; these include:

(1) Refrigeration 100 to 1000 watts

(2) Communication Systems 10 to 1000 watts

(3) Water Pumping 150-1000 watts

(4) Medical Appliances 200 to 2000 watts

Note their small size. Small industrial loads present a more complex picture, and have not been adequately analyzed.

The scales shown here are for highly disaggregated loads. In general, in the past, decentralized power systems (whether using minihydro or diesel generators) have been built at a larger scale, generally over 10 KW or 25 KW. There may be intrinsic factors in the demand situation leading to this outcome, and a market at this scale will undoubtedly persist. However, to

some extent the scale may have been determined by the characteristics of diesel generating sets in use today.

I would like to focus on the more disaggregated loads in part because you are probably less familiar with them and some of the most interesting applications are being designed for them today, and in part because they will provide a basis for comparison with the more conventional decentralized approach.

Water pumping is a good example. Land tenure patterns and ground water levels in many areas of the Third World are such that small independently powered pumps on the order of 15-300 W could be very valuable in increasing irrigation. Until now no viable, proven technology has existed to supply this market. Photovoltaics, of course, are being investigated. I have heard , but not yet been able to confirm, that the Government of India is planning a very substantial implementation program using cells manufactured primarily in India. A possible competitor, however, is a free piston Stirling engine in a configuration which uses the mechanical vibration of the engine directly. We hope to test prototypes of this engine in the next year or two and one of the candidate heat sources is point-focused solar energy. The problem with using direct solar in this way is that the collector has been estimated to cost twice as much as the engine itself on a mass production basis. However, cheaper collectors may be designed. In Hyderabad, parabolic mirrors have been designed which have a material cost of $6.00 and could supply 100 W of power. An intriguing feature of these very small systems is that the construction requirements for collectors may be much simplified, ergo cheaper, for normal weather conditions while it is quite possible that peasants would be willing to store collectors in a safe place during storms or idle periods (that is substitute labor for capital). In designing systems it is important not to assume that an Indian peasant has the same requirements for convenience that an American user does. Note too that power does not necessarily mean <u>electric</u> power.

Very small scale applications of Stirling engines (perhaps also for refrigeration and electricity generation) represent the only move in our

office at present towards high temperature solar thermal power applications. The project has not yet been fully worked out or approved as yet, however.

Small scale applications place at the outset several key demands on energy systems. Their operation and routine maintenance should be simple, they should be reliable, and their capital costs should be as low as possible because the relative cost of capital is higher in LDC's. Maintenance reliability are criteria where currently used diesels fail. To be successful new systems should represent a significant improvement here. This may be more important than whether or not they use oil.

Many engineers with experience in LDC's believe that in general we need to take a new look at heat engines for use in LDC's, perhaps to as large a scale as 10 MW and irregardless of the energy source used. We hope to encourage thoughtful work in this direction in the near future.

In general we do not see a large export market emerging here, at least for complete units.

By large, we mean a major fraction of the domestic market. Much solar equipment is capital intensive, and few LDC's have shown much desire to substitute imports of energy capital equipment for imports of oil, unless the payback time is short. This does not mean that a market for special applications will not exist, or that AID will not subsidize some demonstrations--but both are limited. AID in particular has a total economic assistance budget (excluding Egypt and Israel) of $1.2 billion, which is stagnant and much blood is split in reallocating even a few million dollars. The days when AID financed 2/3 of U.S. electrical generating equipment exports to LDC's are gone.

A more promising strategy is to concentrate on licensing or joint production agreements and export of crucial components (particularly those which require long production runs). There may be many interesting opportunities here as solar technologies develop. From the perspective of a private firm AID's role here is likely to be definition and demonstration of a market, while OPIC (Overseas Private Investment Corporation) can help insure against political and other risks. I must emphasize that AID does

not see itself as a marketing agency for U.S. industry, but in energy AID's (and its umbrella organization, the International Development Cooperation Agency) activities are, in future, likely to have this brokerage element in them in practice.

The following questions were directed to and answered by Mr. Alan Poole, AID:

Q. "What are the motives and objectives of AID?"

A. "The basic purpose of AID is the development of income and stability in developing countries. This is not equivalent to the immediate extension of U.S. commercial aims. However, as has occurred in the past, our involvement with developing countries has an indirect effect on the commercial market which these countries open to the U.S."

Q. "Considering the great distances involved in these cases, product delivery, transportation, and maintenance costs will be phenomenal. This is not including operational training and warrantee costs. Who will absorb these extra costs or responsibilities?"

A. "Traditionally this has been taken care of by the Rural Electrification Authority of the country involved. Service agreements would vary from country to country. This problem dramatically emphasizes the necessity for simplicity and reliability in these systems."

Q. "Since the proposed solar systems would replace existing diesels and assuming that there now exists operational maintenance capabilities for these, would this same level of skills be sufficient for the maintenance of Stirling or Brayton engines?"

A. "Perhaps the best way to answer this question is through actual installation and operation in suitable locations."

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Q. "An expert on OPEC has said that they (OPEC) are unwilling to buy all new U.S. systems; however, they are willing to enter into cooperative agreements whereby in the first 5-10 years they would buy just the systems and then buy the factories. Is there any comment on this?"

A. "Most likely that is the direction that will be taken."

Q. "Have any studies been done concerning introduction of intermediate level technology in developing countries as it relates to economic development? It seems as though there should be a cost effective way to introduce new technology (considering the level of indigenous skill necessary for systems maintenance) without reverting back to 18th century technology. The goal of economic development is not necessarily served by utilizing more basic technology if more advanced technology is feasible."

A. "In all probability this has been considered whether or not a formal study has been performed. Surprises are expected now as older technologies are brought down off the shelf and explored for their potentials. In a general sense, what is being done with solar and wind research is simply an extension of 18th and 19th century technology that has simple, basic, and workable foundations. So the idea presented has a good deal of merit."

Q. "What would be an appropriate perspective of the foreign market for U.S. solar thermal technology?"

A. "Long controversial discussions can and do evolve from a question of this nature; however, it is possible to summarize the situation. The response of most developing countries is receptive, with exceptions. It is generally found that these countries are willing to buy the technology, to buy components, and even to open doors to manufacturing

plants. The exception is that the countries do not want the technology nor the industries to be isolated from the populace through complete U.S. control. The country must be allowed access to and participation in the industries."

A RELATED SOLAR THERMAL APPLICATION

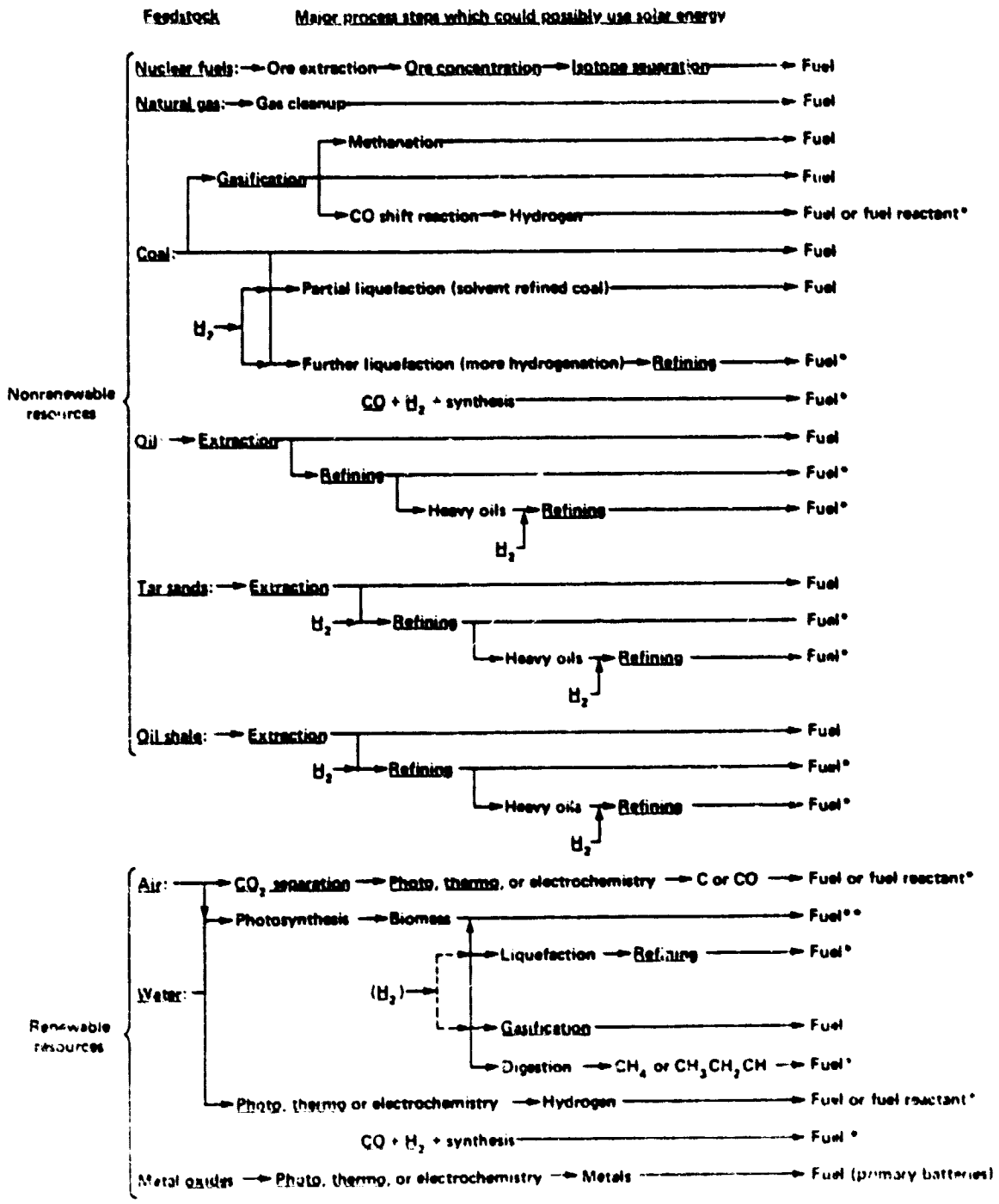
SOLAR THERMAL PRODUCTION OF MOBILITY FUELS

D. W. Gregg, R. W. Taylor and J. H. Campbell

Lawrence Livermore Laboratory

A preliminary evaluation of the technical and economic feasibility of solar thermal production of mobility fuels has been performed. The analysis indicates that there are three areas where solar thermal energy could provide a major assist in the production of mobility fuels in the near to intermediate term. They are Solar Coal Gasification, Solar Oil Shale Retorting and Solar Steam Flooding of Oil Fields. It is assumed that solar assisted production of mobility fuels starting from a fossil fuel resource will be more economically viable in the near to intermediate term than solar fuel systems that start from CO_2 and H_2O. This paper will deal with two of the three above-mentioned areas: Solar Coal Gasification and Solar Retorting of Oil Shale. Both analytical and recent experimental results obtained at the White Sands Solar Furnace are presented.

FLOW CHART FOR THE PRODUCTION OF FUELS



Note: Process steps underlined are potential solar thermal F/C applications

* Transportation fuel or fuel reactant

** Some biological species can yield transportation fuels after only mechanical processing.

COMPARISON BETWEEN A SOLAR COAL GASIFIER AND A LURGI GASIFIER

Product Gas Cost ($/10^6 Btu):

Gasifier	Coal		Oxygen		Solar		Plant		Product Gas
Lurgi	1.4(1.20)	+	0.4(2.20)	+	none	+	2.40	=	$4.96/10^6 Btu
Solar	0.8(1.20)	+	none	+	0.6(1.13)	+	2.40	=	$4.03/10^6 Btu
							Difference	=	$0.93/10^6 Btu

Relative Capital Cost:

Solar Coal Gasifier/Lurgi Gasifier = 1.13

Relative Coal Consumption:

Solar Coal Gasifier/Lurgi Gasifier = 0.57

THE COST OF SOLAR ENERGY vs THE COST OF ENERGY FROM COAL BURNED WITH OXYGEN

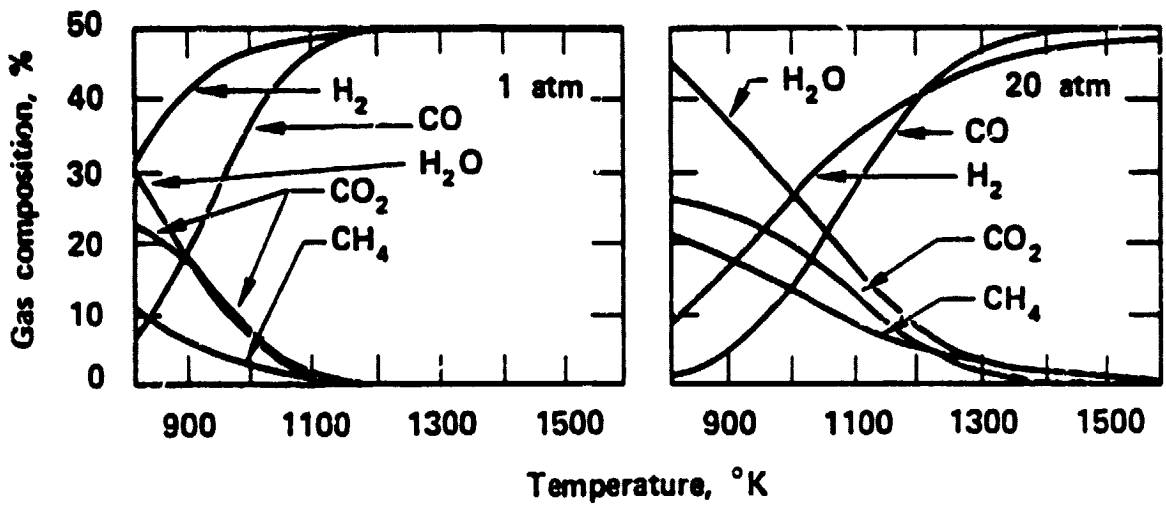
1. Solar Energy:

Solar energy delivered to a point in space by the McDonnell Douglass heleostats for a mass produced, Barstow style Central Receiver Plant costs $1.13/10^6$ Btu assuming 330 days of operation/year.

2. Coal/Oxygen Energy:

The cost of energy produced by burning coal with pure oxygen is approximately $3.40/10^6$ Btu assuming coal at $1.20/10^6$ Btu and oxygen at $25.00/ton.

EQUILIBRIUM GAS COMPOSITIONS OF THE CARBON-STEAM SYSTEM



SOLAR COAL GASIFICATION CHEMISTRY

1. Pyrolysis Chemistry

$$\text{Coal} + \text{heat} \rightarrow \text{char(C)} + H_2 + CO + CO_2 + CH_4 + \text{tars}$$

2. Char Chemistry

   A. Solar Energy Storage:

$$C + H_2O \rightarrow CO + H_2 \quad -31.4 \text{ kcal/g-mole}$$

   B. Heats of Combustion:

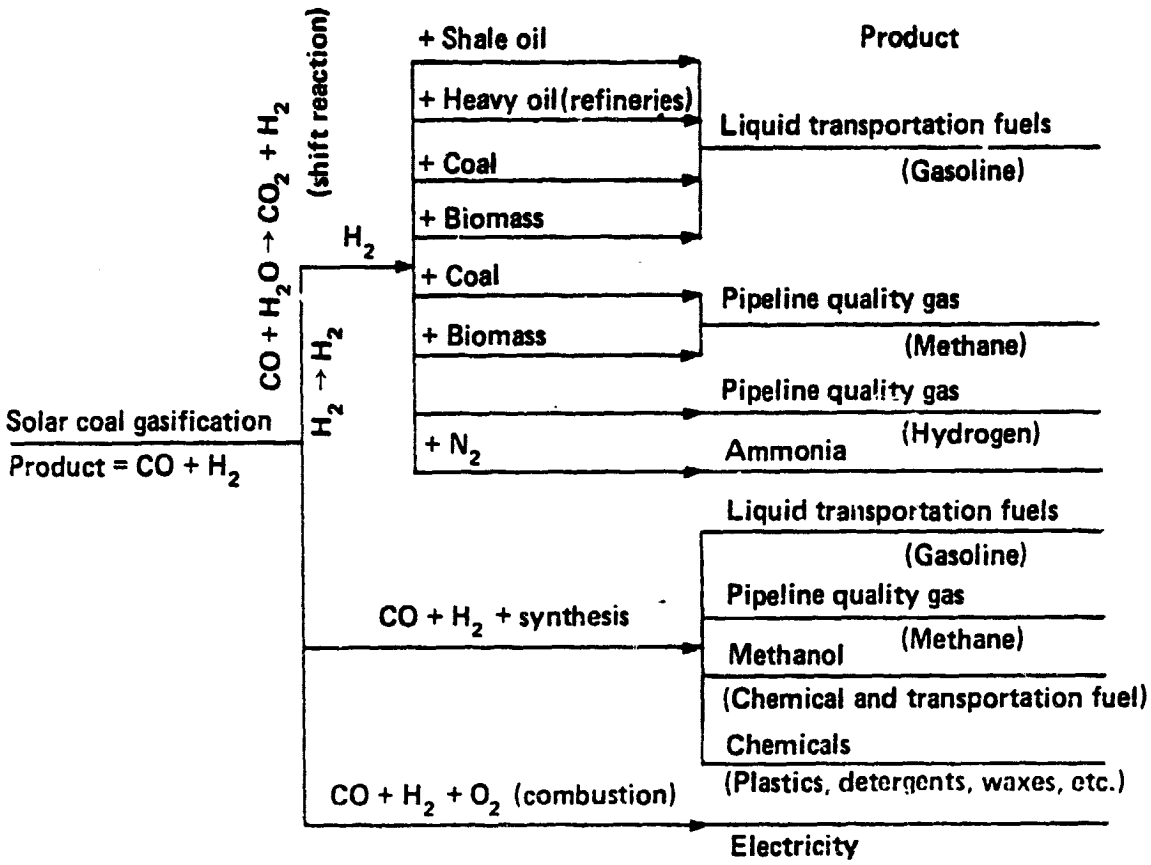
$$CO + H_2 + O_2 \rightarrow CO_2 + H_2O + 125.5 \text{ kcal/g-mole}$$

$$C + O_2 \rightarrow CO_2 + 94.05 \text{ kcal/g-mole}$$

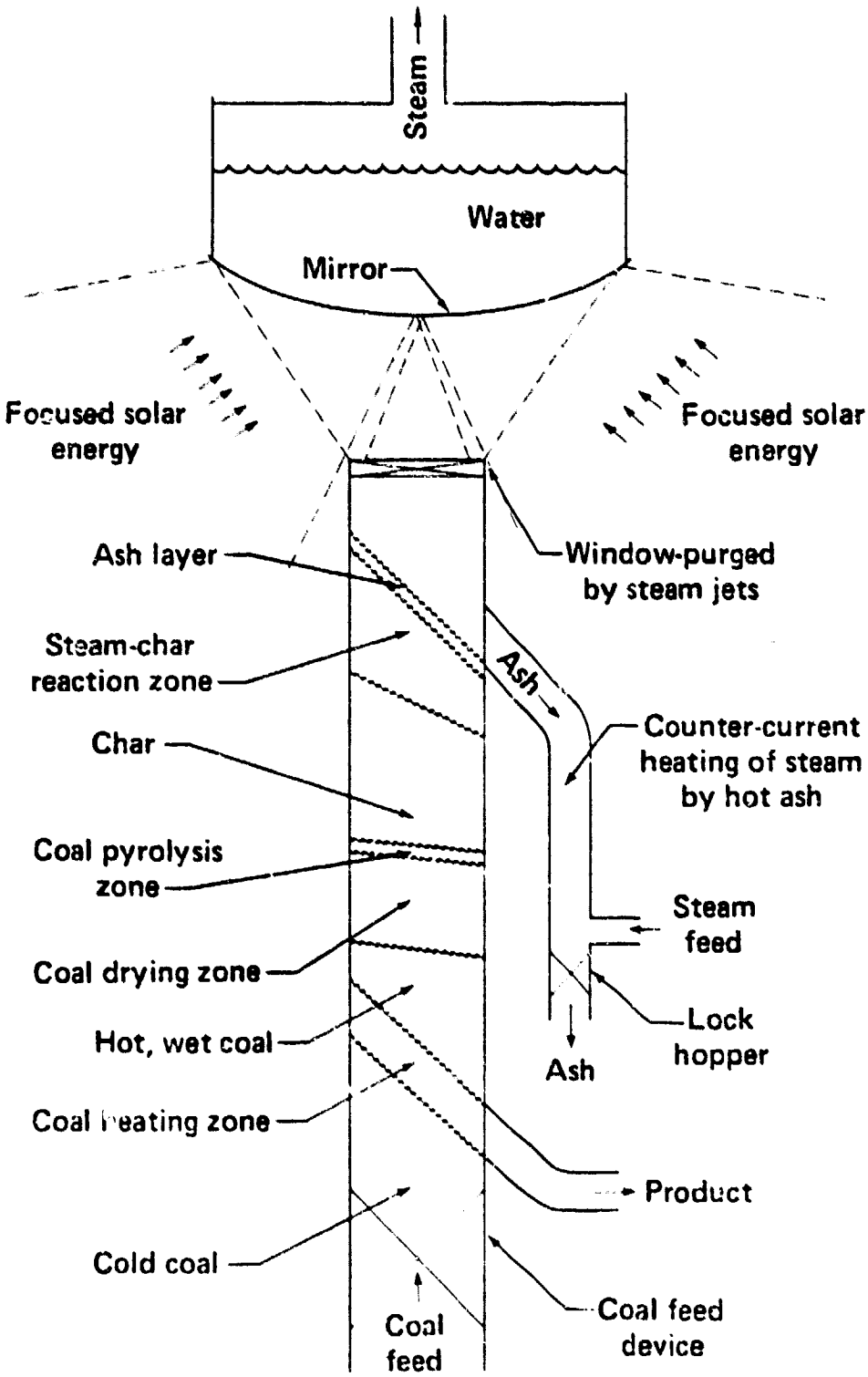
   C. Percentage of Product Gas Heat of Combustion Provided by Solar Energy:

$$(31.4/125.4) \times 100 = 25\%$$

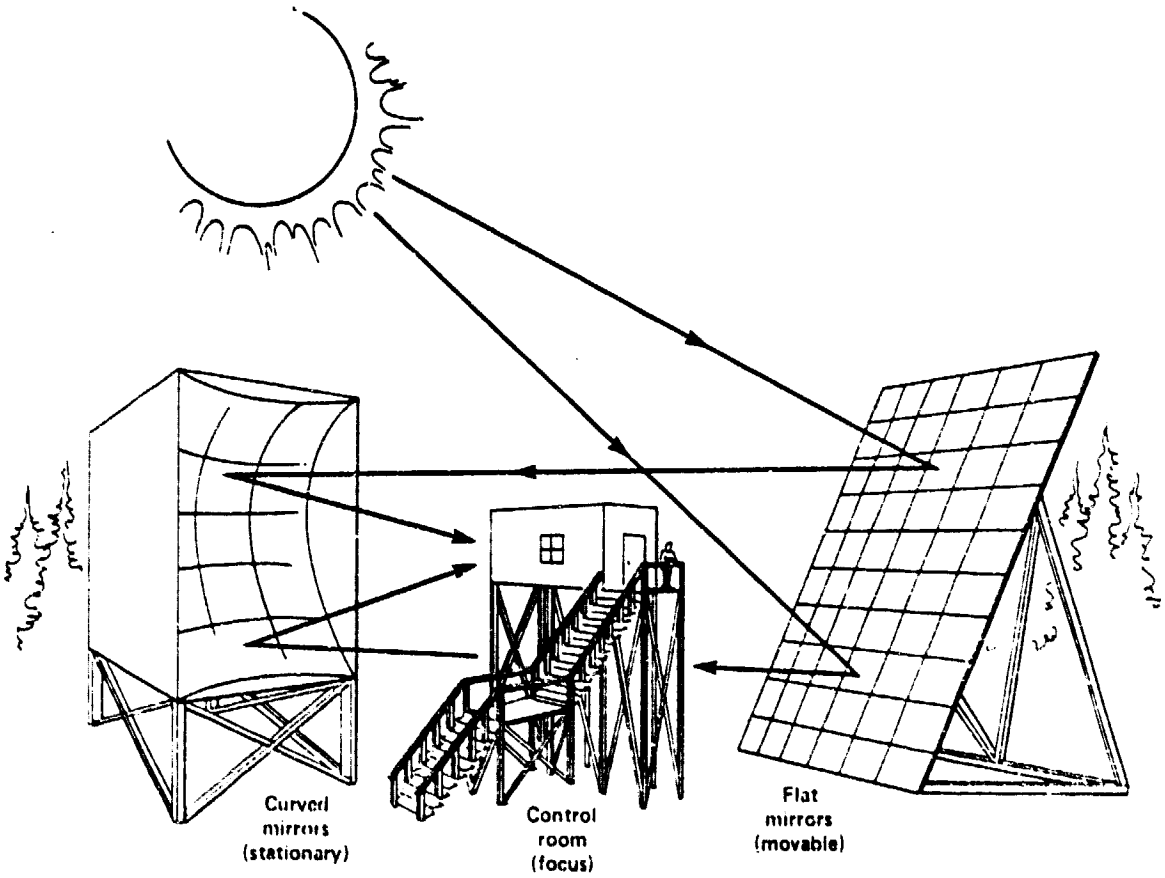
THE GENERIC UTILITY OF SOLAR COAL GASIFICATION



MOVING-BED SOLAR COAL GASIFIER

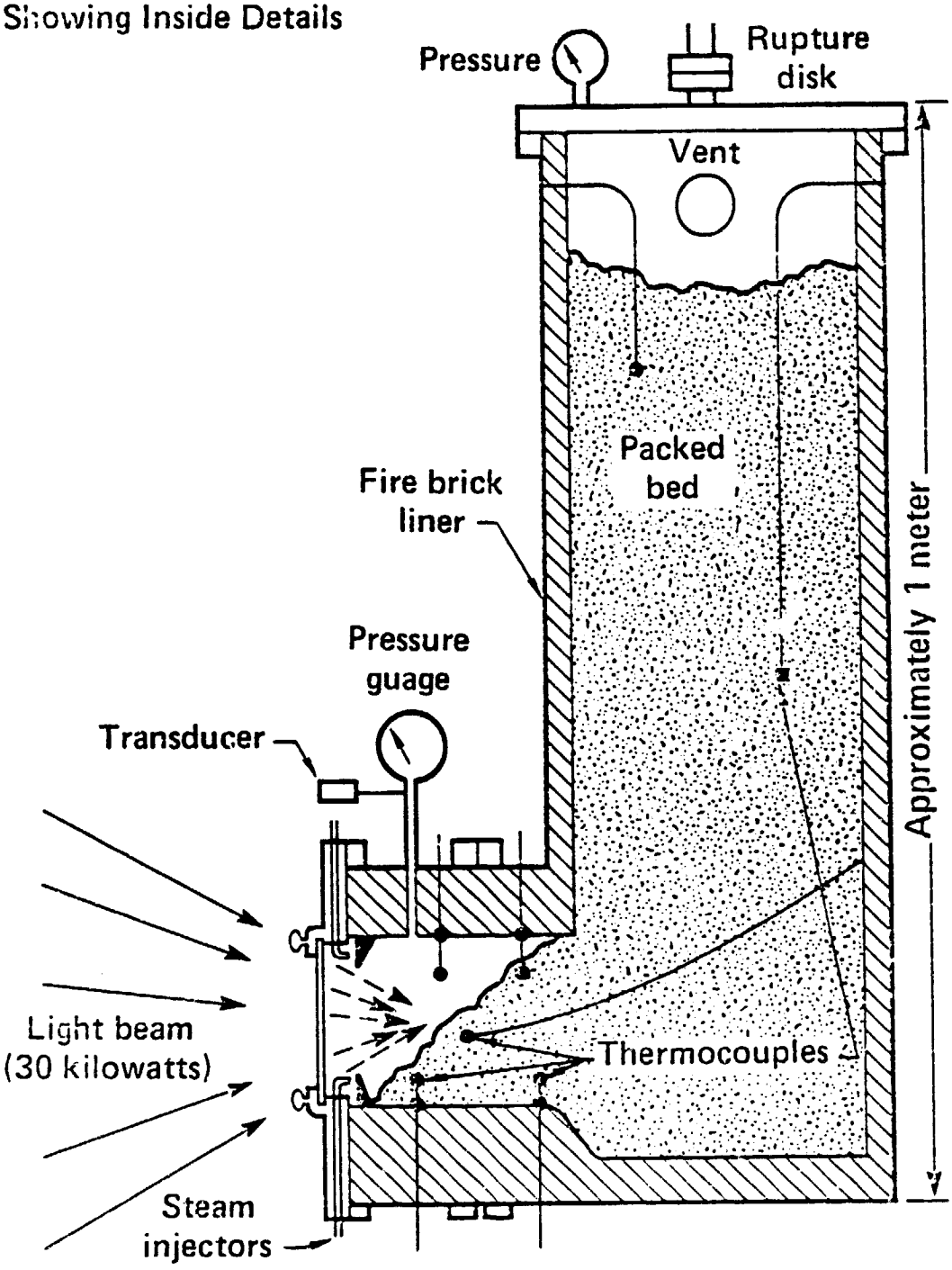


FOCUSED SOLAR FURNACE (30 kW WHITE SANDS N.M.)



SOLAR GASIFIER

Showing Inside Details



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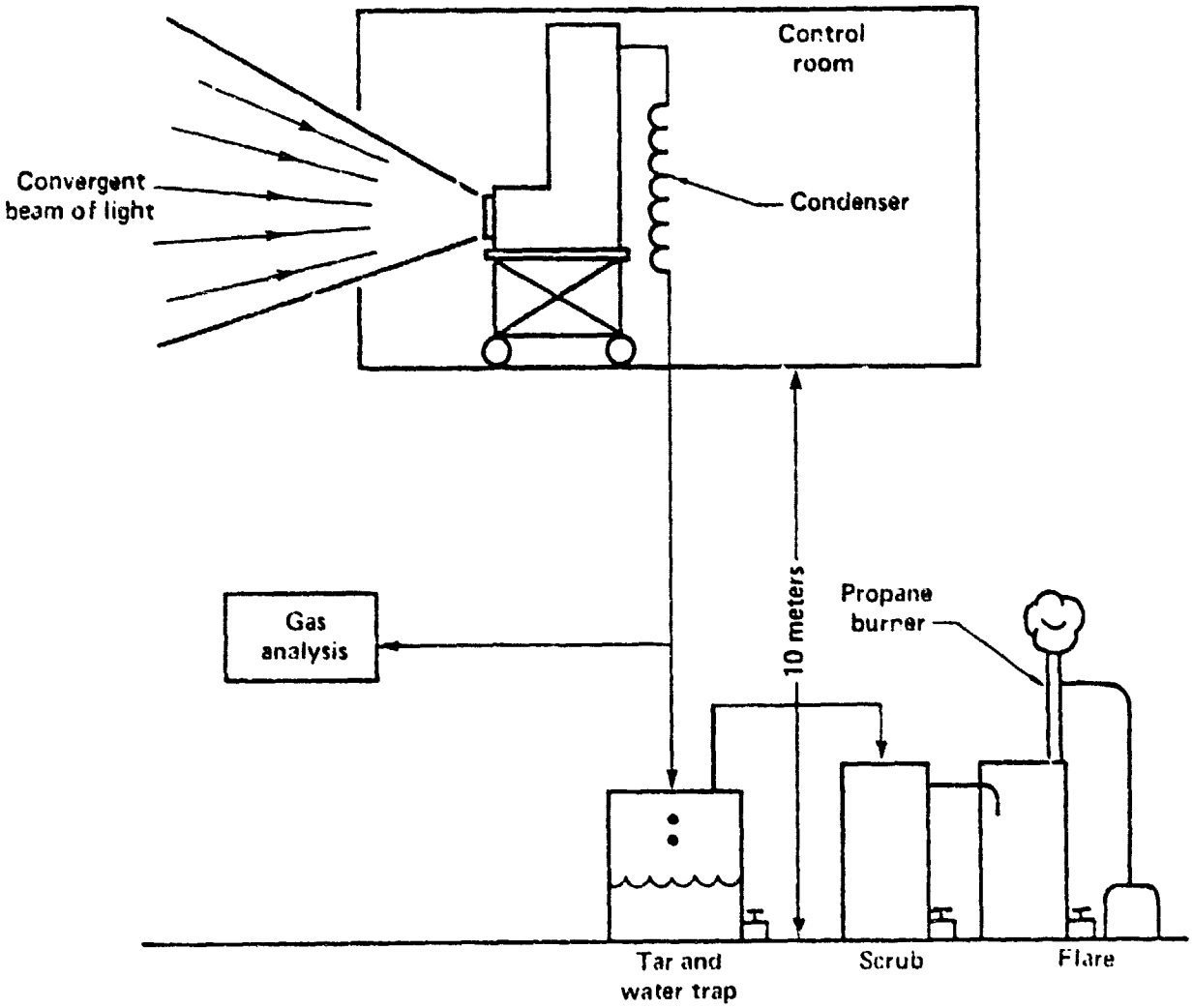
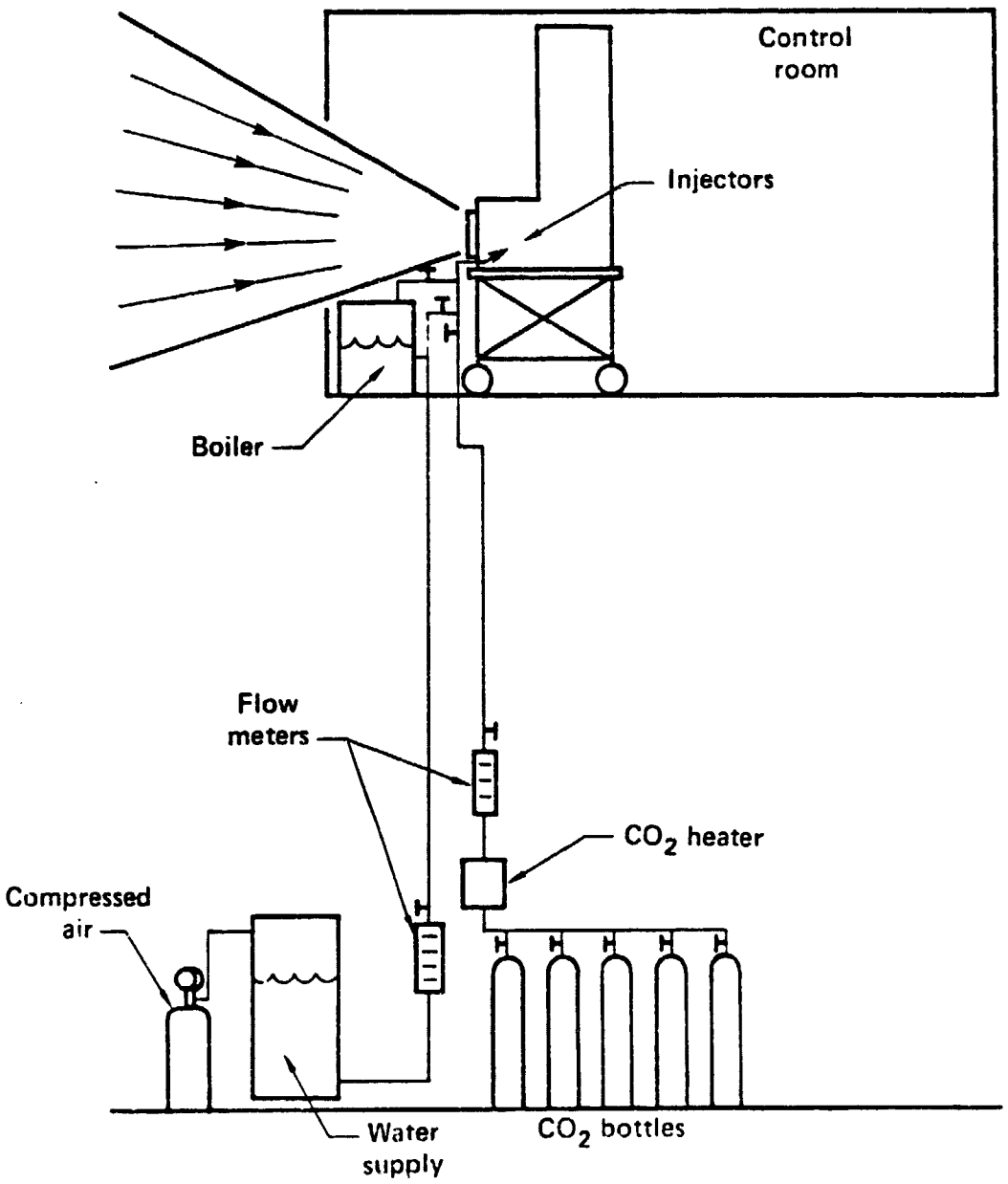
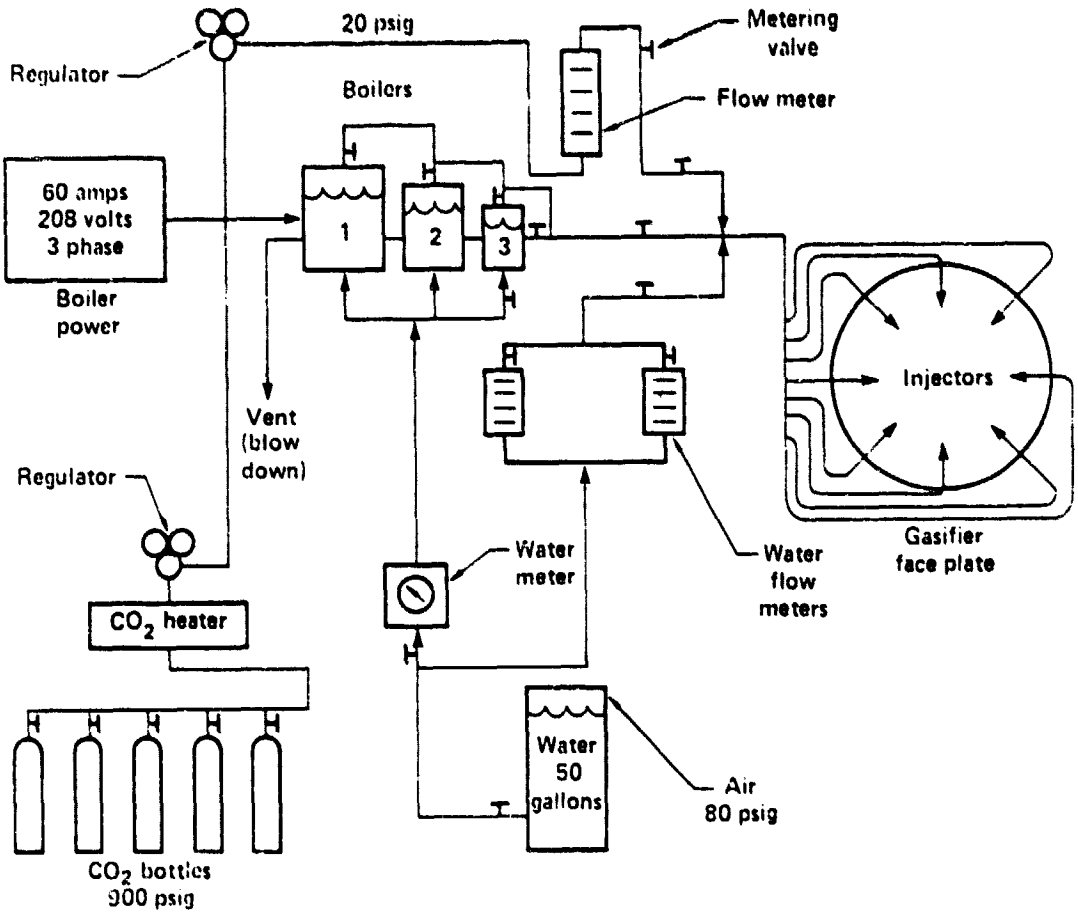
GASIFIER IN CONTROL ROOM (SHOWING VENT SYSTEM)



STEAM WATER AND CO_2 SUPPLY



WATER STEAM AND CARBON DIOXIDE SUPPLY (DETAILS)



GAS ANALYSIS AND SAMPLING FACILITY

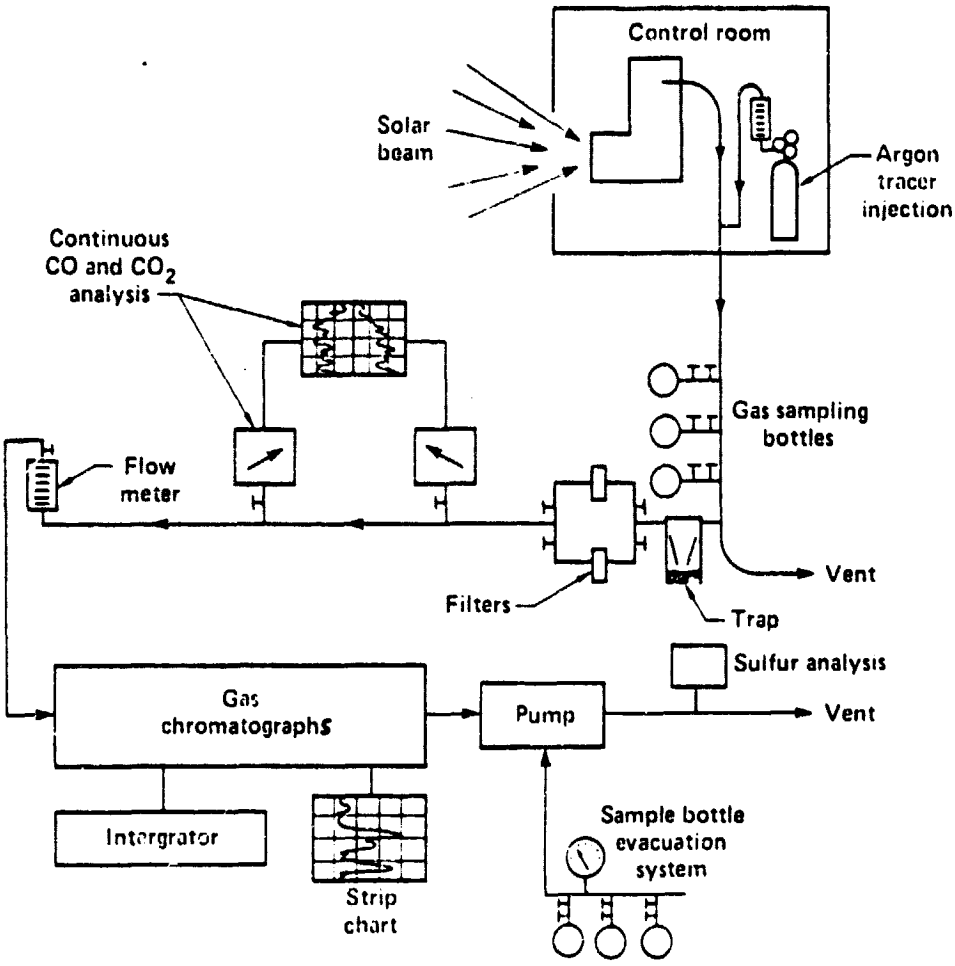


Table 1. Fuel Characteristics.

Type	Density (g/cc)	Particle Size (mm)	Composition wt% (Moisture Free) C	H	N	S	CO_2[a]	ash	Moisture
Subbituminous coal (Rolana)	1.3	30	66.8	5.3	1.1	0.7		9.1	32.9
Activated carbon	0.9	5	93.4	0.6	0	-	0.2	0.2	<0.1
Coke	1.2	10	98.7	0.5	0.6	-	0.2	0.2	<0.1
Walnut shells	1.1	5	46.5	5.4	0	-	0.2	0.5	-
Oil shale[b]	2.3	20	16.0	1.4	0.3	0.1	22.2	87.9	-

(a) Acid evolved CO_2

(b) Colorado shale (24.96 gallons of oil per ton)

Table 3. Efficiency of Solar Gasification

		Experiment No.							
		3	4	4	8	10	11	11	12
	Fuel	Coal	Coal	Coal	Activated Carbon	Walnut shells + Coal	Coke	Coke	Coal
a	Steam flux (mol/s)	0 24	CO_2(.06)	0.24	0.24	0.24	0 24	0.11	0.24
b	Ar tracer flux (mol/s)	9.3×10^{-4}	2.1×10^{-3}	2.1×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}
c	Time into experiment (min)	65	40	110	91	60	78	188	65
d	% Ar	0.74	1.97	1.60	1.18	0.85	3.37	3.92	1.49
e	% H_2	53.2	10.0	58.7	54.8	47.8	53.1	51.3	55.4
f	% CO	23.2	36.9	15.9	29.3	23.4	31.5	33.8	21.4
g	% CO_2	16.2	48.2	20.8	14.2	19.8	11.5	10.5	17.5
h	Fraction steam utilized	0.28	CO_2(0.4)	0.32	0.29	0.35	0.18	.33	.43
i	Solar power (kW)	20.2	10.7	11.3	20.8	15.6	18.6	18.6	22.9
j	Efficiency (percent)*	30	30	50	33	59**	24	22	38

$$* \; j = 100(b)\frac{[134.5(f) + 102.8(g)]}{(d)(i)}$$

** Calculated value probably too high because not all CO and CO_2 came from carbon-steam reaction - some came from pyrolysis.

Table 2. Summary of Solar Gasification and Processing Experiments.

Run No.	Fuel	Objectives	Observations
1	Charcoal	Air combustion to test gasifier window	Window spotted with ash
2	Coal	Air + steam gasification. Window and vent system test	Window kept clean by helical gas flow
3	Coal	First solar gasification with steam, no air	9 kw light input gasified coal at 3 kg/h. Gas was 50% H_2.
4	Coal	Gasification with CO_2 then with steam	Gasification rate with CO_2 ~1/3 rate with steam. Window clean after 4 h
5	Oil shale	Demonstrate rapid heating by solar beam. No steam	Exposure to 20.5 kw beam 10 cm in diam. for 40s resulted in melting shale surfaces (T >1500 K)
6	Oil shale	Retort rapidly using flowing steam for heat transport	Same energy disposition as in #5, temp. rise 800°C/sec. Depth of retorting shallow
7	Oil shale	Retort packed bed with steam. Front face kept at 900 ±50 K	Retorting progressed slowly. Concluded moving bed necessary for practical retorting rates.
8	Activated carbon	Steam gasification as function of solar flux	Gasification rate 2.5 kg/hr at 18 kw solar flux. One-third of steam reacted
9	Oil shale	Retort shale using CO_2 to suppress carbonate decomposition and for heat transport	Process inefficient, confirms #6; moving bed necessary
10	Biomass-coal blend	Demonstrate steam gasification of biomass	Produced 612 mol/h of gas containing 50% H_2, 24% CO, 20% CO_2 and 6% CH_4 at 15.5 kw solar flux
11	Coke	Change solar flux and steam flux	Threshold flux ~10 kw. Rate of gasification at 16 kw was 1.3 kg/h, not sensitive to steam flow, coke unreactive
12	Coal	Change solar flux and reactor position	Max. rate at 16 kw was 4.0 kg coal/hr (2.8 kg carbon gasified/h)

The following questions were directed to and answered by Mr. D. W. Gregg, Lawrence Livermore Laboratory:

Q. "In a combustion process described earlier coal was combusted with oxygen. Why is the coal not simply combusted with air?"

A. "The purpose is to produce a chemical product used in creating mobility fuel, not to generate electricity. Specifically, hydrogen is the desired product, and since combustion in air produces large amounts of nitrogen as well, oxygen is used to remove the nitrogen."

Q. "So is this based on the premise that energy is generated within the coal gasifier by burning that very coal to supply the thermal energy?"

A. "Yes. There are other possible options being tested; however, this is the most economical."

Q. "Has treatment of shale been considered in situ?"

A. "That is impossible by any means."

Q. "Is the sulfur content of the coal removed from the gas?"

A. "Yes, it comes out as H_2S. A CO_2 gasification was run to see if any sulfur could be left in the gas. A test of the gas revealed no H_2S content; however, the tests unfortunately failed to check for COS. H_2S can be easily removed with a liquid exchange system."

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REQUIREMENTS FOR PORTABLE POWER

MILITARY THEATER APPLICATIONS AND REQUIREMENTS FOR ADVANCED ENERGY CONVERSION TECHNOLOGY

Richard G. Honneywell, 2d Lt, USAF
Thomas E. Hausfeld

TECHNOLOGY INTEGRATION CONSIDERATIONS

- MILITARY RESEARCH AND DEVELOPMENT PROGRAMS
- TECHNOLOGIES LINKED TO OPERATIONAL REQUIREMENTS
- ORGANIZATIONAL PROCESSES TO TRANSLATE REQUIREMENTS INTO PRODUCTS.

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MARKET PENETRATION STUDY

PHASE I

- IDENTIFY AND LIST DOD POWER REQUIREMENTS.
- DEVELOP DOD REPLACEMENT SCHEDULE.
- DEVELOP DOD LIFE CYCLE SCHEDULE.

PHASE II

- IDENTIFY SPECIFIC DOD POWER REQUIREMENTS.
- SELECT BEST POWER SYSTEMS FOR APPLICATION.

OBJECTIVE: ESTABLISH DECISION MODEL TO AID IN SELECTION OF ADVANCED POWER SYSTEMS.

METHODOLOGY:

- DETERMINE OPERATIONAL REQUIREMENTS
  - QUALITATIVE
  - QUANTITATIVE
- CHARACTERIZE SELECTED TECHNOLOGIES
- DETERMINE SYSTEM VALUES BY INTEGRATING OPERATIONAL REQUIREMENTS WITH DATA BASE.

RESULTS: RANGE OF SYSTEM VALUES.

SYSTEM PARAMETERS

- PERFORMANCE
  - EFFICIENCY
  - RELIABILITY
  - LIFETIME
  - OPERATION AND MAINTENANCE
  - GROWTH POTENTIAL
  - START UP/SHUT DOWN
  - THERMAL ENERGY AVAILABLE

- PHYSICAL
  - FUEL CONSUMPTION
  - VOLUME/SIZE
  - WEIGHT
  - ENVIRONMENTAL CONSTRUCTION

- COST
  - ACQUISITION
  - LIFE CYCLE

SYSTEM VALUE METHODOLOGY

SYSTEM VALUE = RATING X UTILITY

RATING DEFINED BY USER PREFERENCES

UTILITY DEFINED BY DATA BASE

ATH RATING VALUES

- PERFORMANCE

EFFICIENCY	.90
RELIABILITY	.95
LIFETIME	.60
OPERATION AND MAINTENANCE	.95
GROWTH POTENTIAL	.25
START UP/SHUT DOWN	.70
THERMAL ENERGY AVAILABLE	0

- PHYSICAL

FUEL CONSUMPTION	.90
VOLUME/SIZE	.90
WEIGHT	.98
ENVIRONMENTAL CONSTRUCTION	.40

- COST

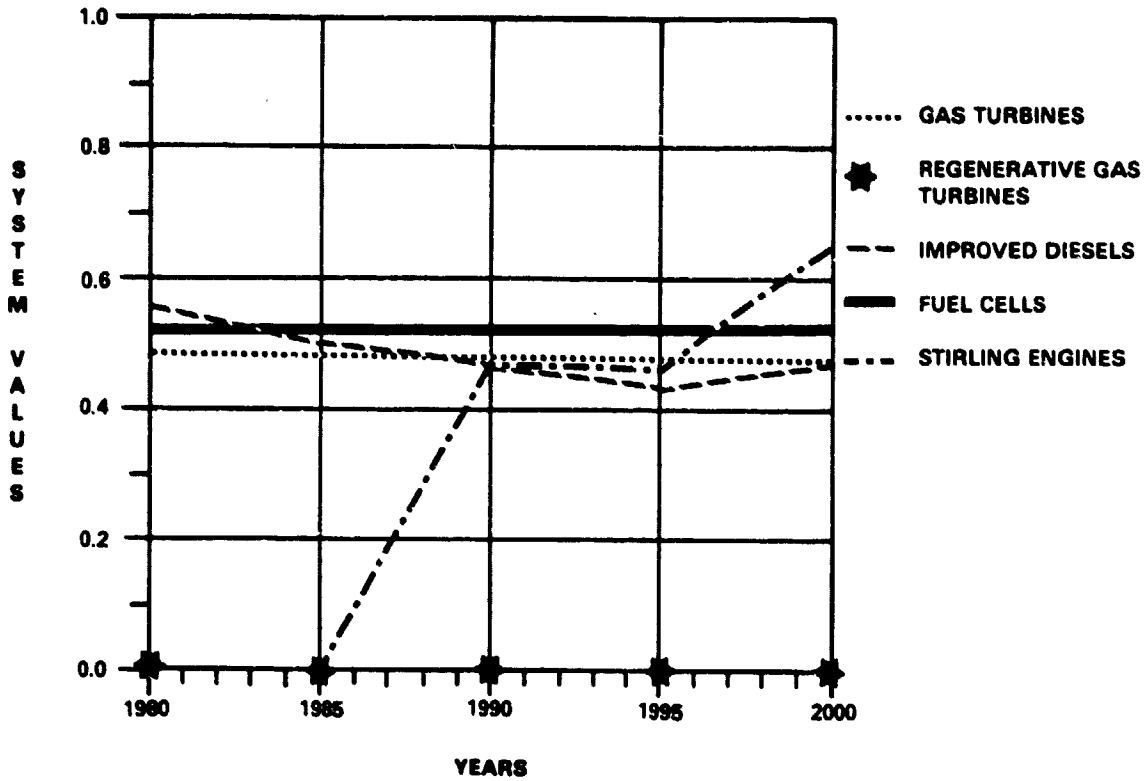
ACQUISITION	.60
LIFE CYCLE	.40

- <u>OVERALL RATINGS</u>

PERFORMANCE	.95
PHYSICAL	.90
COST	.65

POWER SYSTEM SELECTION FOR AIR TRANSPORTABLE HOSPITAL

50 KW (60 Hz 30 480V), CONTINUOUS



CONCLUSIONS

- ADVANCED POWER SYSTEMS CAN MEET NEW SYSTEM REQUIREMENTS:
  - INCREASED SURVIVABILITY
  - REDUCED OPERATION COST
  - REDUCED MAINTENANCE
- OPERATIONAL REQUIREMENTS MUST BE DEFINED QUANTITATIVELY AND QUALITATIVELY.
- OPERATIONAL REQUIREMENTS MUST BE LINKED TO ADVANCED TECHNOLOGIES.
- MARKET PENETRATION POTENTIALS FOR ADVANCED POWER SYSTEMS MUST BE BASED ON THREAT, REPLACEMENT SCHEDULES, AND LIFE CYCLE.
- SYSTEM TRANSITION MUST BE ADEQUATELY PLANNED.

The following questions were directed to and answered by Lt. Richard Honneywell, AFPL:

Q. "There are three questions concerning the computer program that characterizes various generating systems. What system is it on, what language is used, and is it available?"

A. "It is on the computer system at Wright-Patterson in FORTRAN and is available."

Q. "Has any work been done in the areas of solid state UPS?"

A. "We have found that there is work that needs to be done with UPS; however, there are no specific programs assigned in that area. Consideration will have to be made for allocating some R&D money for this."

Q. "Have solar systems been considered for support of nuclear missile sites?"

A. "It appears that solar support alone is not feasible for underground missile locations. Currently, power requirements are being studied for the MX missile program, but further information cannot be disclosed here."

Q. "What are the different systems that have been studied?"

A. "The Terrestrial Energy Study examined 18 systems to explore broad range possibilities to satisfy all our energy requirements. The mobile and tactical systems which we have looked at include gas turbines, fuel cells, Stirlings, and advanced diesel. Plans are to include wind and solar systems through new work with DOE."

ARMY MOBILE ELECTRIC POWER: APPLICATIONS AND REQUIREMENTS

Written by Sherman Grazier and
Presented by Tom Batty

INTRODUCTION

A little background information is necessary to lead into my presentation. I am in the Support Branch of the Concepts and Studies Division, of the Directorate of Combat Developments, of the U.S. Army Engineer School, which is one of the service schools under the U.S. Army Training and Doctrine Command (TRADOC). The mission of TRADOC is to prepare the Army to win the next war by developing proper doctrine, tactics, organizations, materiel systems, logistical systems and training systems. The service schools are the operators for TRADOC, each having proponency for its military area of interest, for example: Signal School for communications. The Concepts and Studies Division has often been likened to the locomotive of a train. Through studies and analysis it produces operational concepts. The concepts are the basis for development of doctrine; the rationale for writing field manuals; and for the development of materiel requirements, organizations, logistical support and the training required to prepare individuals and units to employ the concepts in battle.

The operational concepts describe:

What needs to be done and why - the desired result

The concept:

- How it is to be done
- Where it is to be done
- When it is to be done
- Who does it
- What is needed to do it - tactics, equipment organizations, logistic support, training.

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The Support Branch, as its name implies, has responsibility for concepts dealing with engineer combat and service support to the Army in the field. Mobile Electric Power is one of its areas of responsibility. That brings us back to me. One of my major responsibilities is to accomplish the process for Mobile Electric Power.

The U.S. Army Engineer School appreciates the opportunity to participate in workshops like this for several reasons. They provide a means of communicating Army requirements and objectives. They also are a vehicle for acquiring information which may have application to combat development activities.

In response to Mr. Hauger's request, my presentation will cover the following subject areas:

- Army MEP requirements
- Available MEP system
- Extent of Army MEP usage
- MEP problems
- Operational constraints
- Liquid fueled/solar heated system
  - operational design criteria
  - non vehicular fueled system
- Modular system vs single unit system

Army MEP Requirements

The Army currently has three Department of Army approved requirements documents for MEP items. Two requirements documents are being considered for approval.

Brief descriptions of the requirements are as follows:

Qualitative Materiel Requirement (QMR) for a Family of Military Design Electric Power Plants. (Approved 30 Nov. 1970).

This requirement is for a Family of Military Design, multi-purpose electric power plants providing power ratings and frequency options shown in Figure 4.

Power Rating (KW)	Hertz
5	60
10	60
15	50/60/400
30	50/60/400
60	50/60/400
100	50/60

These power plants will be required to operate on vehicle fuels readily available in the theater of operations. They will be multi-purpose, simple to operate and maintain, highly reliable and durable, and low in fuel consumption. The power plants will be transportable in standard vehicles (all power ratings) and all phases of airborne/airmobile operations (5 and 10 KW sets only). In comparison with current engineer-generator sets this family will provide improved performance, greater reliability, higher power density (KW/pounds), increased standardization, less maintenance, lower noise levels, and lower life cycle cost than the current family of generators. All power plants will be designed to minimize detection by aural, visual, photographic, infrared and radar devices. Power plants will be protected from nuclear effects to the same degree as the supported weapon system.

Dept of the Army Approval Materiel Need for a 10KW Member of a Family of Military Design Electric Power Plants. (Approved 25 Sept 1972).

This requirement document was prepared to allow expedited development of a gas turbine driven member of the Family of Military Design Electric

Power Plants. As a member of the family, all characteristics and parameters stated in the above QMR apply. This generator set consists of a gas turbine engine with speed reduction gearing coupled with a 3600 RPM AC generator. It is complete with all accessories and control to provide 10KW of utility power at 60 Hz. The unit is of an open design using a skid base and tubular frame construction. The design goal for the unit is 250 lbs., MTBF of 500 hours, and overhaul life of 6000 hours.

Dept of Army Approved Required Operational Capability (ROC) for a Family of Silent Lightweight Electric Energy Plants (SLEEP). (Approved 1 May 1975).

Current electric power generating sources are extremely susceptible to aural and IR detection, endangering personnel and equipment in their vicinity in addition to hampering the using units' ability to listen for enemy activity. A generator set that is difficult to detect by visual and aural means will enhance the combat capability of friendly tactical units, allowing weapons and surveillance systems along with other support equipment having electric power requirements to be deployed in forward areas. Operation of a vehicle engine to drive its generator and maintain battery charge in stationary use creates poor fuel efficiency, rapid and undue wear of the vehicle engine, and makes the vehicle susceptible to enemy detection because of its sound and high IR heat source. Existing generator sets are designed for one fuel. Some combat vehicle engines require automotive gasoline and others use diesel fuel. For generator sets to be logistically and tactically compatible with their transport vehicles, multifuel design is desirable (provided the energy process is other than a piston engine driven electrical power generator or unless the energy process provides benefits that outweight the logistical penalty of a single or special fuel).

Studies conducted by Army and other agency development activities conclude that establishment of the proposed family of silent power sources is feasible and within the state of the art for a number of advanced energy conversion technologies. Rankine cycle engine-generators and fuel cells appear to be the most attractive for the power ratings up to approximately

5KW; and an enclosure-silenced, open Brayton cycle is appropriate for ratings above 5KW. Other development considerations include Wankel-engine generators (developments being pursued by UK and FRG); Stirling-cycle engine generators; and multi-fuel thermoelectric generators for low power ratings. SLEEP generators will be authorized only in those specified units where noise discipline is essential to the performance of tactical missions, e.g., maneuver brigades and forward.

The 1.5KW fuel cell is the first member of the Family (.5 to 5KW) to be developed. The initial design is a phosphoric acid electrolyte fuel cell with a hydrogen generator using a methanol reformer. Development of a hydrocarbon fuel cell is scheduled under the SLEEP program. This thermal catalytic system will produce hydrogen from gasoline, diesel or JP-4. The hydrogen will be used with currently available hydrogen-air fuel stacks. The cracker, stacks and control equipment will constitute a set.

Parameters and characteristics for SLEEP are listed in Figure 6.

Predicted performance parameters compared to current standard set (1.5KW GED) are shown.

Parameters	1.5KW GED	1.5KW F.C.
1st Cost - $/KW	600	600 - 1000
Wt - Lbs/KW	80	70
Fuel - Lbs/KWHR	2.0 - 2.2	.75 - .90
Fuel	Gasoline	Methanol
Noise - Meters (Inaudibility)	1000	1000

As previously mentioned, the Engineer School is coordinating two power related requirements. On deals with solid state power conditioners and the other with a standardized power distribution system for units in the field. The concept is to use power conditioners and only 60Hz tactical utility type generators. Power conditioners will provide for frequency and voltage conversion; and will provide for uninterrupted power when supported with

storage batteries, fuel cells, commercial power or other auxiliary power sources. Characteristics such as weight, size and cost savings realized from the simplification of current generators are key to the acceptance of the concept.

The increasing complexity of electric power requirements within units has increased the danger of injury or death to those deploying distribution systems and of damage to generators and weapons systems. Methods and equipment used for unit power distribution must be simpler, safer and standardized. A Standard Family of Power Distribution systems will perform processing functions such as circuit paralleling. Standardized cables and connectors, keyed and sized for voltage and amperage will be used. The system will contain circuit breakers, grounding equipment and protection against electromagnetic pulse (EMP).

The overall goal of these two requirements is to reduce the types of generators to 60 Hz AC with standardized distribution systems delivering power to using equipment. Power requirements other than 60 Hz AC will be provided by use of solid state power conditioners located at the using equipment.

Currently Available Power Generators

In the early 60's the numbers of different makes, models and sizes of field generators in the DOD inventory had risen to over 2000. Logistic support was unmanageable. In 1967 a DOD Project Manager was established as the single focal point for mobile electric power. This office has established a standard DOD Family of Mobile Electronic Power Generators consisting of about 40 different generators. Figure 8 contains the members of the DOD Standard Family of Power Generators.

Army Uses of MEP

Currently the Army uses all sizes up to 200 kw as mobile generators. The larger sizes are used for installation power. The numbers of the various kw ratings in the DOD inventory provide an insight as to the existing size of the Army power market. Roughly 10% of the number of generators fielded is used as an annual replacement factor.

Some of the kw ratings between .5 and .10 will be replaced by SLEEP generators. The ROC for the SLEEP generators originally stated that a figure of 91,944 SLEEP generators would be fielded. This uses the number resulting from a one for one replacement scheme. The procurement plan now envisions using SLEEP generators only in brigade and forward areas. The changes resulting from this concept are shown in Figure 10.

ITEM	EXISTING NUMBER	NEW NUMBER
1.5 kw 60 hz	22051	6139
1.5 kw 28 V DC	11475	3058
3.0 kw 60 Hz	15820	1824
3.0 kw 400 Hz	2379	1235
3.0 kw 28 V DC	10810	3700
5.0 kw 60 Hz	21813	1446

The existing numbers cannot be justified on a cost and operationally effective basis at this time.

MEP Problems

Assuming that complaints received from field users can be related to problems with the current MEP sets, the greatest problems reported deal with reliability and noise. Field units want generators that run longer without constant attention. Generators must run more hours without requiring repair at the unit level. Field units say that generators are so noisy their noise can be used to locate the unit. This is a tactical vulnerability that the SLEEP sets are designed to reduce. The noise from current generators makes verbal communications difficult and can cause hearing damage. Design of future generator sets must consider noise suppression measures.

A third potential problem is fuel. DOD is trying to reduce the requirement for gasoline on the battlefield. Diesel engines are supplanting gasoline engines in increasing numbers. However, this does not reduce significantly the overall requirement for liquid fossil fuels. In view of uncertainties in availability of liquid fossil fuels, new fuels and engines that can use them should be a high priority research item. A major consideration with introducing a new fuel will be the handling and storage requirements associated with the specific fuel.

A potential problem under investigation is infrared emissions. Generators emit IR signatures that can easily be detected by electronic sensors at considerable distances. Thus, the generator and in turn the weapon systems it is supporting can be vulnerable to attack, especially when guided heat seeking munitions are used. Parameters are being developed for use as design criteria for suppression measures.

Operational Constraints

The Army must be prepared to fight worldwide in all climates, day or night, against well trained and equipped opponents, in a nuclear environment, and WIN. The current emphasis is on the European battlefield but the theaters of operations must not be overlooked. Thus, natural operational constraints exist. Others are the result of technical considerations. Over the years, Military Standards and Specifications have been developed in an effort to standardize equipment. These guidelines also impose constraints on equipment development.

One of the most important constraints (requirements) of the Army in the field is mobility. Mobility can be equated to transportability. Several considerations make transportability a critical factor in equipment design.

Counterfire equipment has become so sophisticated that many units must adopt "Shoot - and - Scoot" tactics to survive. The ability to "Scoot" depends on mobility. The Army has developed a standard Family of generator/trailer and truck combinations which will maximize transportability. Descriptive data on the combinations is contained in TM 750-5-32,

Army Equipment Data Sheets, Generator Sets and Electric Power Plants, Truck and Trailer Mounted.

Currently, generators are restricted to using the same fuels that are provided as fuel for Army vehicles. There is good rationale for the restriction. Most of the generators are driven by internal combustion engines as are the vehicles. The amounts of fuel used by generator sets is small in comparison to that used by vehicles. It then follows that bulk fuel handling equipment should be, and is, designed to handle fuels used by vehicles. This philosophy results in minimizing the number of types of fuels required on the battlefield. In 1973, it became obvious that a shortage of petroleum fuels could develop that would put the Army in a highly vulnerable position.

It is recognzied that petroleum fuels will be required for the foreseeable future. Prudence, therefore, requires a significant reduction in dependence upon petroleum fuels. This can be achieved, in part, by exploiting different energy sources and synthetic fuels and development of engines appropriate for their use.

Units in the field have a tendency to consider reliability as an unalienable right and maintenance as a necessary evil to be accomplished only when absolutely necessary. This attitude is understandable. The reason the unit is in the field is to accomplish a mission. It has specialized equipment designed to accomplish the mission, for example, an 8" Artillery gun. The generator that provides power is considered a support item; the gun is the mission essential item. Any time spent on servicing and maintaining the generator detracts from time available for operating the mission essential item. This attitude may sound unrealistic. However, the mechanic who repairs the generator doubles in brass. He is also the mechanic who repairs the truck that hauls ammunition for the 8" gun. The mission essential item will be given priority of attention. From a lifecycle cost and operational effectiveness viewpoint, the equipment that has a higher initial acquisition cost and lower upkeep cost (people, fuel, and parts) will probabily be chosen over an item with a low acquisition cost and high upkeep cost. The cost of owning the item is

lower. Therefore, units want generators that run longer and require less maintenance and upkeep.

Internal combustion engines and gas turbines are inherently noisy because combustion noises are exhausted to open air. Even though mufflers are attached, decibel levels from current generator sets range from around 85 to 100 dBa. Noise at this level causes hearing damage, interferes with speech and permits aural detection or location of generators at a distance. MIL-STD 1474A, Noise Limits for Army Materiel, Mar 75, provides design standards developed from consideration of hearing damage-risk, speech intelligibility, aural detection, and state-of-the-art of noise reduction. The standards are intended to cover typical operational conditions.

The ROC for the SLEEP generators mentioned above stated a requirement for inaudibility at 100 meters. MIL STD 1474A states that the following octave band pressures at a measurement distance of 6 meters must not be exceeded in any band if non-detectability is to be achieved at 100 meters.

Limiting Octave Band Levels (dB) for Aural Non-Detectability

Hz	63	125	250	500	1k	2k	4k	8k
db	60	46	44	45	45	46	47	48

The above data provides guidance for inaudibility at 100 meters. While materiel developments are proceeding, an area of indecision exists concerning the distance. The distance in the ROC was established for a jungle environment. The question of whether 100 meters is appropriate for the European battlefield is under investigation. If the non-detectability distance can be extended to say 400 meters, sound suppression measures should result in a lesser amount of weight and cost. Of course, if an appreciable decrease in the distance is necessary, the reverse would be true.

Infrared or thermal signatures produced by military equipment has been the source of growing concern to the military in recent years. Thermal detection and heat seeking munition technology has advanced to the point

where, if the heat source can be detected, it can be hit. The vulnerability that exists must be overcome or survival of equipment on the battlefield will be precarious, at best. Thermal blankets, enclosures and directional exhausts have achieved varying measures of thermal suppression on existing equipment. An opportunity exists with equipment in the design stage to exploit available technology to reduce the inherent thermal signature. Then, if additional measures are necessary, a greater overall reduction of thermal signatures should be attainable.

Visual detection and recognition of an item depends primarily on its shape or silhouette. Other cues, such as color, reflections and motion, contribute to visual detection of an item. Visual observation is considered to be direct observation with the unaided eye or augmented by use of optical equipment. Interpretation of aerial photography is generally considered to be direct observation. The effective range of ground based visual observation is about 3-4 kilometers. This figure is the result of terrain indulations, vegetation, and other obscurants on the battlefield. Aerial observation extends the range to much farther distances. Again, if an item can be seen, it can be hit. Therefore, distinctive shapes, reflections from glossy surfaces and unnecessary movement either of parts of the equipment or of people around the equipment must be avoided.

Liquid Fuel/Solar Heat Combustion System

In theory, an engine that can use any form of fuel found locally to drive a generator should be ideal. For installation or semi-permanent power requirements, such a flexibility in choice of fuels can result in system design and operational cost savings. Fuel options have long been a major consideration when designing a commercial power plant. Several conditions, both logistical and tactical in nature, reduce the flexibility in fuel choice for MEP generators used in the field. Heat engines can be called multi-fuel engines in that they can by using different combustion equipment burn several types of liquid fuels, or gaseous fuels, or solid fuels or obtain heat from a solar source. One combustion technique cannot

burn all liquid and solid fuel efficiently. Thus, to maximize fuel flexibility, the Army inventory would contain several types of combustion equipment which can be used interchangeably based on fuels found locally. Alternatively, the Army must choose one or at most two combustion techniques and develop a logistic system based on the associated fuel(s). Only a complex cost and operational effectiveness analysis could determine which of the above options would be more effective. Intuitively, I would choose the alternative with fewer combustion techniques because on the surface it would appear to be easier to support logistically. Of course, it is just this philosophy which led the Army to standardize an internal combustion engine's burning gasoline and diesel as fuel. This philosophy is valid as long as the chosen fuels are readily available. The Army now finds that because of uncertain availability of liquid petroleum fuels, it is prudent to investigate the potentials of different fuels and engines appropriate for their use. The fuel to be acceptable must not significantly add to the existing logistic burden. The engine must reduce logistical support and meet operational requirements contained in approved requirements documents. If the fuel can replace liquid petroleum fuels for production of electric power under the above conditions, the impact of a serious fuel shortage may be reduced.

Introduction of a new fuel for generators may have some adverse impacts which must be considered. An example is the logistical impacts which would result from the introduction of methanol as a fuel. Methanol will require a dedicated handling system. This is an undesirable but probably inevitable situation. Another consideration is the percentage of liquid fuel saved in relation to the overall requirement. A cost/benefit ratio analysis may show that the percentage saved is so small as to not outweigh the cost of handling required. An indication of the relative fuel savings percentage is indicated:

Equipment	gal/hr
XMI Tank	34.3
M113 Carrier	5.6
5T Cargo Truck	3.0
5 KW Generator	1.4
5/4 T Truck	1.2

The figures are relative but they do indicate intuitively that the amount of fuel used by generators is a minor percentage of the total fuel requirement.

Modular vs. Single Unit Systems

Modularity provides maximum potential of flexible arrangement to achieve a total power requirement. A family of appropriately sized single unit generators provides the modularity required. Some constraints to a completely modular system must be considered. The numbers of modules that can be combined are limited by the sizes of trailers and trucks available for transport of generators. A standard family of Power Units has been developed for Army use. Basically, the goal of the family is to standardize designs and prevent proliferation of both design and sizes of transport equipment. The current family is contained in TM 750-5-32. With rare exception, the number of generators mounted on a trailer or truck has been limited to two. This limit was established to minimize the size of transport equipment. In addition, the numbers of trailers and trucks available to tow trailers have been severely reduced in Army units. Therefore, a system that requires additional numbers of either trailers or trucks will not be received favorably by the users. They will not have trucks to tow the trailers, nor people to drive additional trucks.

Paralleling of generators is already a standard practice in the Army. Procedures and techniques are contained in Army publications such as

FM 20-31, Electric Power Generation in the Field. In the design of generation equipment, consideration must be given to the fact that there is no formal training for generator operators. The operations of generators and the deployment of power distribution cables within units is usually accomplished as an additional duty by low ranked soldiers. Paralleling procedures must, therefore, be appropriately uncomplicated.

Summary

The U.S. Army Engineer School recognizes the urgency and necessity for reducing the Army's dependence on liquid petroleum fuels. It also recognizes certain impacts on the Army that will result from successful development of synthetic fuels and engines appropriate for their use. Early exchange of information between representatives of equipment users and research analysts is extremely important.

When analysts are aware of user requirements and constraints and the rationale for their existence, the introduction of the resulting equipment into the Army can be accomplished with much less turbulence. This is because the item invariably has more utility designed into it.

In closing, I want to restate two points:

It is essential that the Army be provided with power plants having improved reliability, increased service life and reduced, simplified maintenance.

To insure an ability to accomplish its missions, the Army must reduce its dependency on petroleum fuels. New fuels and engines for their efficient use must be developed.

The following questions were directed to and answered by Mr. Tom Batty, USAES:

Q. "Considering that the Army is looking for replacements for the gasoline engines that currently power generating systems, if an advanced efficient Stirling or Brayton cycle heat engine were to be available in comparable sizes, would the Army seek procurement?"

A. "Certainly an engine that is quiet, efficient, cheap, simple, adaptable and can be operated by anyone is quite in demand. Such an engine would definitely be considered."

Q. "Does the basic design of the existing 10KW gas turbine generator make it amenable to modification for acceptance of a solar heat source in addition to other fuel sources?"

A. "A baseline engine that is being proposed for solar energy is currently natural gas design that can accept any fuel. This is a different type engine than is manufactured elsewhere. There are technologies that utilize combustible heat sources and can be adopted to convective heat receivers."

Q. "Is the IR signature known for solar engines working in this mode?"

A. "Openly there is quite a bit of controversy over opinions. The work that is being done on this topic is classified. Appropriate inquiries and clearances could obtain this information. It can be said that a temperature differential of a few (1-2) degrees can be pinpointed at very long distances."

Comment

"It should be noted that there are quite a few parameters other than temperature gradients that must be considered when analyzing target vulnerability. Temperature differentials may not be the key targeting mode."

RENTAL APPLICATIONS AND REQUIREMENTS

Vernon H. Waugh, Jr.
Curtis Engine and Equipment, Inc.

For the past thirty years Curtis Engine has been selling and renting Engine Powered Generators. Curtis had an informal program for Rental Power until 1976. At that time a formal program and department was created.

We have supplied generators under the Rental Program for over 25 states and more than 30 countries. Our generators are backup power for hospitals, industry, government, military, and security services.

When the call comes, Curtis is there, at 2 in the afternoon or at 2 in the morning, seven days a week, 365 days a year. Complete mechanical service backs the Rental Fleet at all times.

The Rental Program and Fleet is based in Baltimore. Our locations in Washington, Norfolk, and Wilmington all are storage locations for the rental fleet. With central control of the Rental Program the most applicable equipment can be supplied for the customer's needs.

Curtis Engine is not a rental house. We are regional distributors of diesel engines, generators, and generator sets/systems. These products include Onan, Perkins, Allis Chalmers, Chrysler, and White Hercules. Our facilities produce custom built generator sets from 5 kilowatts to 1 megawatt.

The Rental Market for Engine Powered Generators has grown over the past ten years. The more demand for our electrical power, the increasing growth the Rental Market will experience.

Wherever people are working or playing you will find an increasing need for electric generating sets. This need may be for a few seconds or up to a few years. The applications for Rental Generators come in all types, sizes, and shapes. The reasons for "Rental" can range widely. For the purpose of:

A. A temporary need for electrical service.

B. Or a need for power at one or more locations to meet a specific need or needs.

The Rental and Sales markets for generators are normally closely related. The major difference is the Sales Market also serves the load/peak sharing market.

We have provided Rental generators for 2 1/2 kilowatt to the megawatt range. Hospitals, ships, industries, schools, shops, churches, Army, Navy, Coast Guard, Air Force, lighting companies, sound companies, EPA, DOD, DOE, advertising, Boy Scouts, Single Phase, Three Phase, 50 Hertz, 60 Hertz, 110 volts to 600 volts.

Rental generators have provided prime and backup power for hospitals, ships, industrial, offices, etc., and 50 hertz power for government and industry. One unit provided power to test a computer used to judge the Miss Universe Contest this year.

We have developed a 30 kilowatt noise reduced unit we call our Silent Electrical Power System. This unit has provided power with low noise levels for Radio and Television Productions, Movie Locations, Music and Theatrical Groups. The unit was field tested on Preakness Day in the infield at Pimlico Race Track, Baltimore. Over 70,000 people were contained in the infield. The generator provided power for the rock groups Nantucket and Appalossa.

Over the past years the Rental Market has been developed by customer and potential customer education. Educated to the advantages of a Rental Unit. The advantages of availability, convenience, and economics. The Rental Unit is available immediately. The Unit can be moved from location to location.

The time is near where the factor of ECONOMICS will play an increasing roll in the Rental Market. The cost of temporary service from the utility is growing. The utility is increasing the cost for temporary service to meet their actual cost. In the past the charges for temporary service were below actual cost for the utility to install the temporary lines. The utility recovering the additional installation cost through the monthly power consumption charges.

With the temporary service charges increasing and the installation time of 90 to 150 days common, more and more contractors are turning to the Rental Generator.

Additionally the utilities are starting to charge for demand or peak times. The construction and industrial areas' users are testing the use of a Rental Generator to provide a portion or all of their needs during the peak rate hours.

A clothing manufacturer in a Western Maryland plant is divided into two identical production lines with the same power consumption. The utility provided the power for one line and a Rental Generator provided the power for the second line. Due to the higher charges from the utility (during the coal strike in 1978) and the increased demand charges, the manufacturer provided 50% of his own power. Using a total cost program of Rental, Fuel, Maintenance, and Repair, the "Rental Power" was 10 to 12% lower than the utility power.

This economical approach is increasing as the cost of electrical service grows. This approach is from the monetary standpoint and not the energy conservation approach.

Rental generators fall into two major types of general utilization. These types are:

A. MOBIL

B. TEMPORARY

MOBIL USER

The users have a purpose that requires some degree of mobility. Having a generator that is portable or semi-portable is a necessity to meet their needs. Customers having this type of need we classify as MOBIL Users.

TEMPORARY USER

Requiring the need for a generator for short term or a nonpermanent use are classified as a TEMPORARY user. The following examples will identify the temporary user:

In a hospital in Washington main substation failed and one of the two out-dated and poorly maintained generators also failed. Curtis supplied six truck loads of generators to split the hospital's load in order for repair crews to rebuild a substation. Within six hours the hospital was back to nearly full power.

A shipping company has eight refers to maintain for several days. To extend the life of their individual refrigeration units, reduce fuel consumption, and service personnel requirements, a Rental Generator provided power for all eight units.

An industrial plant working seven days a week and several months behind on orders is told by the local utility that their power will be off for a day. It is nesessary to up-grade the power lines for a new plant, for another company, being constructed in the same area. The industrial plant is faced with two days to stop the production line, one day lost for the outage, and three days to restart the production line. The utility rented our generator with operators to supply the industrial plant. The plant was down 24 minutes instead of 6 days.

THE THIRD GROUP-BUYERS

The third type of Rental users can be made up from either group. The Rental Program becomes a purchase plan to acquire needed equipment. Large corporations with tight controls on capital expenditures sometime force purchasing agents into a rental purchase plan. Rentals begin as a short term item and may extend into a long term purchase transaction.

Depending on the time frame and the dollar amount of the rental, a user in either the Mobil or Temporary group can move into the third group-Buyers.

The following outline the Mobil and Temporary applications with examples of each type.

MOBIL APPLICATIONS:

FIRE DEPARTMENTS	Pumpers, Lift Buckets, Rescue Units, Ambulances
POLICE DEPARTMENTS	Communications Vans, Crime Prevention Units, Aviation Control Units.
MEDICAL SERVICES	Emergency Care Units, Mobil X-Ray and Dental Centers, Prevention Screening Vans, Veterinary Services.
UTILITY	Aerial Lift Trucks, Municipal Sewer Inspection, Underground Air Ventalization.
TRANSPORTATION	Truck Refrigeration, Pumps for Compressed Gases, Containerized Refrigeration.
MOBIL SERVICES	Beauty Palors, Animal Care Units,Training Centers, Ice Cream and Snowball Vendors, Book-Mobiles.
DISPLAYS	Computer and Copier Display Vans, New Product Demo Units, Sales Centers, Floats.
NEWS MEDIA	Mini-Cams, Control/Tape Centers, Remote Productions.
RECREATIONAL	Campers, Motor Homes, Boating.

TEMPORARY APPLICATIONS:

CONSTRUCTION	Subway, Pumps, Welding, Tools, Fans, Heaters, Pipe Fusing, Insulation Services.

ELECTRICAL SERVICE	Hospitals, Office Buildings, Plants, Stores, Warehouses, Railroads, Model Homes.
SHIP SERVICE	Prime Power, Loading & Unloading, Construction, Dredging, Dry-Dock.
PUBLIC EVENTS	Fairs, Carnivals, Shows, Concerts, Sporting Events, Church Events.
TESTING	Environmental and Industrial Testing, Natural Resources Drilling, (Off Shore Drilling).
AGRICULTURAL	Florists, Nurserymen, Dairymen, Poultrymen, etc.
LIGHTING	Construction, Stage, Security, Special Events, Sporting Events.

Rental Generator range is from 2500 watts up to 1 megawatt. Approximately 60% of the normal rentals fall in the 15 kilowatt to 200 kilowatt range.

To best meet the rental customer needs, the configurations of the units are as follows:

2 1/2 to 5 kilowatt are portable units with hand carrying frames, 120 or 120-240 volts, single phase with standard outlets. Most units are gasoline powered. (50 to 60 Hertz) one to three gallon mounted fuel tank.

6 to 15 kilowatt are skid mounted or mounted on light duty trailers, 120-240 volts, single phase with standard outlets. All units are diesel powered and have mounted industrial type mufflers. (50 to 60 Hertz) eight to twenty gallon mounted fuel tank.

15 to 250 kilowatt are skid mounted or mounted on tamden axle trailers, voltage reconnectable, 3 phase, 1 phase, residential mufflers. All units are diesel powered. (50 to 60 Hertz) 50 to 275 gallon separate fuel tank.

275 kilowatt and up are semi-trailer mounted in 20 or 40 units, 120-208 or 277-480 volts, 3 phase, with residential mufflers. All units are diesel powered. (50 to 60 Hertz) built-in 500 gallon tanks or larger.

To support Rental Units we back our rentals with 24 hour emergency service. In 1978, 22¢ of every Rental Dollar was spent in equipment maintenance, 4¢ for on-site repairs, and 18¢ for preventive maintenance.

In today's market there are approximately 250 generators in an active rental market for the Baltimore-Washington area. Nationally there are estimated to be 3000 generators, 15 kilowatt or larger in the rental market. We refer to an active market of generators specifically allocated for rental applications. There are many generator sales organizations that will place a new unit on rental for a long term rental (6 months or longer). After the rental is terminated, the unit is sold as a used generator.

The Rental Power Business today is very competitive in some areas of the country, and nonexistent in other areas.

To meet the needs of the entire market or a large portion of it, one must maintain a large balanced inventory. To meet customer's needs our rental fleet comprise over 150 units, 60% of the Baltimore-Washington Market's inventory of Rental Power.

The Rental Power Business can be profitable. One must rent their equipment nearly 70% of the time to achieve a return on investment within two to three years. To justify a multi-million dollar inventory the balance of unit sizes and rentability must be matched.

Over the past thirty years we have learned what specifications and design to build or buy for the Rental Market. We start with a base generator, add mufflers, breakers, quick change voltage switch, fuel tank, operating instructions, skid base. Selecting the unit with the right engine model, air cleaning and fuel filtering system is a must to protect the investment in a Rental Fleet.

Advantages and Disadvantages of Solar

Over the past several months we have had some degree of diesel fuel supply problems. We have not lost a Rental due to this problem but it is a serious concern for a customer and potential customer.

From a logistic standpoint of supplying fuel and fuel tanks, a solar system would reduce or eliminate this problem. There would be no need for large tanks or refueling problems at job site. The safety problem of storage of flammable fuels would not be eliminated. Ninety-five percent of service problems with Rental Generators are with the engine drive end of the generator set.

Environmental problems of noise and exhaust pollution would be eliminated. Today's technologies are working toward greater efficiency of engine powered systems. Work is done daily to reduce noise and air pollution.

To deploy and operate a 15-20 kilowatt solar system with a 30 foot diameter collector would be impossible for some locations and difficult in other locations. This size unit would not conform with space requirements and some site requirements. At other sites to give access to direct sun light, the unit may be placed at a distant location. The distant location would require a larger solar system to compensate for voltage drop. This same problem occurs in engine powered generators if the unit is located close to the consumption point.

A solar unit would require a high degree of fool-proofing and vandal-proofing, like an engine powered unit. This requirement would be needed to protect the safety of operators, equipment, and surroundings.

A multi-fuel system would be the best marketing tool to introduce the solar system. The user would have the advantages of solar and the piece-of-mind that the backup system would supply his needs. Once solar technology reaches a point of acceptance as a total source the single solar system would be acceptable. The solar unit would be lighter, less costly to maintain, more maneuverable, and overall less costly.

The following questions were directed to and answered by Mr. Vernon Waugh, Curtis Engine, and Equipment, Inc.:

Q. "There is a problem associated with the use of solar systems as back-up or reserve power systems concerning cost effectiveness and power storage. Obviously it is cheaper to have a diesel system than a solar system waiting in reserve since solar becomes cost effective with use. If solar were to be used in a rental capacity, would the use factor be great enough to make that application feasible?"

A. "For an application where the unit remains unused in a purely back-up position the cost would make a solar system prohibitive. Seventy percent of my rental equipment is actually used however. So if a modular system existed that could be plugged into conventional equipment to operate as main or auxilary power, it would probably be a good, marketable product. We would be willing to buy and rent such systems."

Q. What is the lifetime of a typical generating system being used now?"

A. "A piece of equipment is kept on the rental fleet for 2 to 3 years depending on its size and application. It is then sold as used equipment."

Q. "Whereas the military has to plan for X years to implement technology, if a useable system became available on the market in the near future, can you foresee purchasing this equipment as soon as it is available?"

A. "Yes, and this certainly should be considered realizing that the lead time for generators from most manufacturers is roughly 4 to 7 months."

Q. "If the opportunity existed for you as a private businessman to enter into some type of cost sharing demonstration with the government with the type of equipment discussed here, would you be willing to try such a program?"

A. "I would imagine that it would be advantageous for us to try such an endeavor. It would be a step forward, and this would fit into our goal of being a regional leader in the business."

Comment

"From all discussion concerning mobile power, it seems apparent that an excellent market exists for solar concentrators with multifuel engines. There is probably a larger market for the engine than for the collector module. Perhaps if the engines open the market, it will be much easier and cheaper for solar to enter."

Q. "Could an estimate be given concerning the lead time before this technology became a significant part of your inventory?"

A. "This would depend on cost and efficiency. As an estimate, over a 5 to 10 year period approximately 50 percent of the rental fleet could be converted."

Comment

"This is a good point to note that the time frame which must be anticipated for success in any manner is 5 to 10 years. This type of technology, though available, may not emerge overnight for reasons of testing, training, etc."

Q. "When a customer rents state-of-the-art generating equipment, what is the cost to him for the power generated?"

A. "For current rental equipment, the cost per kilowatt is roughly three times that of commercial electricity in the Baltimore/Washington area."

Q. "If a generating unit is bought and then the cost written off taxes, how do the same rates compare?"

A. "It is still more expensive by about 25 percent. This is size sensitive and applies to below 250KW units."

Q. "How would utilities respond to industries 'peak shaving' by various onsite generating equipment or systems, perhaps with existing backup systems?"

A. "I am not quite sure of the legal details involved nor of how the utilities would respond to this. There is a law in existence now which requires utilities to buy back any surplus of power (being produced by independent systems) at 3/4 of their selling rate. This is to alleviate the production demand. It should be stressed that we have not become involved with the details of the law, we only know that it exists. An actual case that we are dealing with, where a hospital is producing steam and electricity on an independent basis, has shown a complete payback period of seven years."

Comment

"A true cogeneration system running 7 days a week, 24 hours per day, can be paid off almost anywhere in the U.S. in two years, virtually everywhere in three years. In New York, it can be paid off in one year. The degree of cooperation from the utilities varies from coast to coast. For example, in California the utilities will do all in their power to support installation of cogeneration units. Conversely, Consolidated Edison of New York will desperately try to prevent such installations. For years, the independent generation of any electricity in VEPCO was legally prohibited. Now that law has been removed.

"California has recently made some progressive changes. California utilities will buy energy from independent producers, then sell electricity back at a lower rate. Currently PG&E will buy electricity at $83.00 per KW per year. Additionally they will pay between 38 mils and 50 mils depending on time of day and time of year. The same energy is resold at an average of $40.00 per KW. The rationale is that they are paying for the incremental or marginal cost. Since most generation capacity was installed in this country at $150.00 to $250.00 per KW. Incremental power, considering actual power cost, deferred cost, and interest on investment, is being put in at $1500.[illegible] $2000.00 per KW. Hence, the incremental power is what is being replaced, and the utilities must sell to all users at a consistent rate."

"President Carter, in a published program, has said he would pass legislation that would force other utilities to do the same."

Q. "Concerning the private household rental and sales market, is there a substantial group of the population with large amounts of disposable income that would be willing to buy systems to become independent (off the grid)? This question seems reasonable due to the current American attitude of independence and self-sustenance."

A. "This has happened already in the Baltimore area where a person bought a system for his private business application, and his residence was in the same building. In most cases now, the systems cannot be cost effective enough to provide the necessary incentive. However, it only seems reasonable that as systems do become more cost effective this will occur."

Comment

"It is interesting to learn from these discussions that an engine which could be derated without loss of efficiency would be quite applicable in many generating capacities. It should be pointed out that this is the thrust of the new recuperated engines that are coming out now."

REVIEW OF CURRENT

APPLICATIONS EXPERIMENTS

THE SMALL COMMUNITY

SOLAR THERMAL POWER EXPERIMENT

TARAS KICENIUK, EXPERIMENT MANAGER

JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

The Department of Energy (DOE), through its Division of Central Solar Technology, is engaged in an effort to develop the technology for the practical and economic collection and conversion of sunlight into electricity. Solar thermal electric systems of the type being developed for this project are capable of supplying a portion of the nation's electric power needs. This experiment seeks to validate the system design and assist in the ultimate commercialization of the technology.

In carrying out its directive to further this effort JPL has proposed a project called Community Solar Thermal Power Experiment which is designed to meet the following objectives:

1. To establish technical readiness of small point-focusing distributed receiver technology in a small community/utility environment.
2. To determine economic, performance, functional and operational aspects of the selected system in a user environment.
3. To stimulate the creation of an industrial base for small community power systems.
4. To advance acceptance of the small community power system by the user sector.
5. To identify institutional barriers associated with the utilization of small power systems in the small community sector.

The experimental facility is a Solar Thermal Electricity Generating Plant which will be closely associated with a small community. The plant will have a nominal peak rating of one megawatt and is to be designed without energy storage, except that short period buffer storage systems may be incorporated to lessen shock due to transient clouds, changing loads, etc. A visitors facility will serve to explain the purpose and function of this visible operation.

The plant will occupy a site of less than nine acres, and will be surrounded by a secure enclosure. The shape of the field is not predetermined, but will depend upon the character of the site, yet to be selected.

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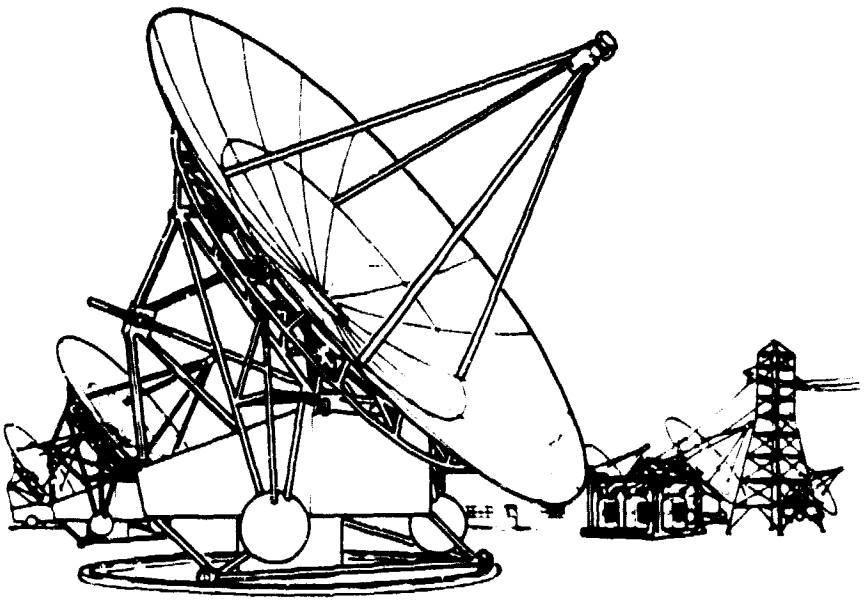
The collector subsystem consists of distributed parabolic reflecting concentrators approximately 11 meters in diameter with their associated receivers located at each focal point.

The distributed electrical generation system which has been proposed employs one generator located at each concentrator. The energy conversion device is a Rankine cycle engine. In this scheme, the working fluid is heated by the sun's energy focused within the cavity type receiver and transported via very short ducts or pipes to the engine which is located in the vicinity of the focal point of the concentrator.

The experiment will be carried out by a consortium in partnership with the government and consisting of the system integrator and of a site participation team. This team will have at least one power generating or distributing utility as one of its members. The remaining members are expected to provide valuable experience and assist in solving both construction and operating problems. The government will be responsible for the construction and installation of the solar portion of the plant, including the electrical generators, but excluding the distribution system.

PROJECT DESCRIPTION



- A SOLAR THERMAL ELECTRIC POWER SYSTEMS EXPERIMENT EMPLOYING PARABOLIC DISH TECHNOLOGY ADDRESSING THE SMALL COMMUNITY APPLICATION SECTOR

PFDR TECHNOLOGY FOR SMALL COMMUNITY APPLICATIONS

- HIGHLY MODULAR
  - BROAD APPLICATION RANGE
  - INCREMENTAL GROWTH
- HIGHLY VERSATILE
  - ELECTRICITY
  - PROCESS HEAT
  - HYBRID - MULTI FUEL
- COST EFFECTIVE
  - HIGH COLLECTION/CONVERSION EFFICIENCY
  - MASS PRODUCIBLE

PROJECT OBJECTIVES

GENERAL

- ESTABLISH SYSTEM FEASIBILITY OF POINT-FOCUSING DISTRIBUTED RECEIVER TECHNOLOGY IN A SMALL COMMUNITY APPLICATION ENVIRONMENT
- DETERMINE ENVIRONMENTAL, OPERATIONAL, ECONOMIC AND INSTITUTIONAL CHARACTERISTICS
- ADVANCE COMMUNITY ACCEPTANCE
- INITIATE CREATION OF AN INDUSTRIAL BASE FOR SYSTEMS, SUBSYSTEMS AND COMPONENTS

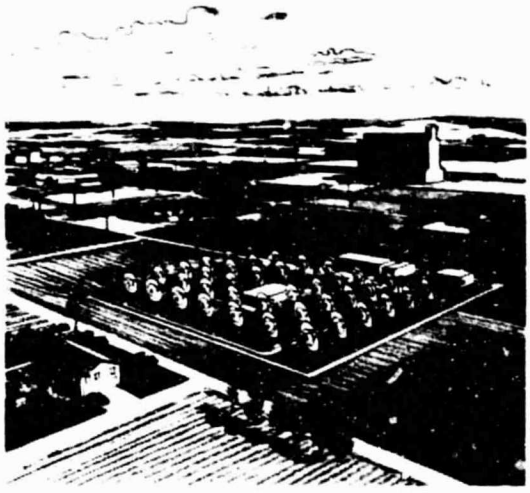
PERFORMANCE

- SYSTEM PERFORMANCE OBJECTIVES WILL BE DETERMINED AT COMPLETION OF CONCEPTUAL DESIGN

BRIEF DESCRIPTION OF PLANT

APPROXIMATELY 10 ACRE SITE WITH 65 PARABOLIC CONCENTRATORS, EACH 11 METERS IN DIAMETER AND EACH HAVING ITS OWN:

- RECEIVER
- ENGINE
- GENERATOR

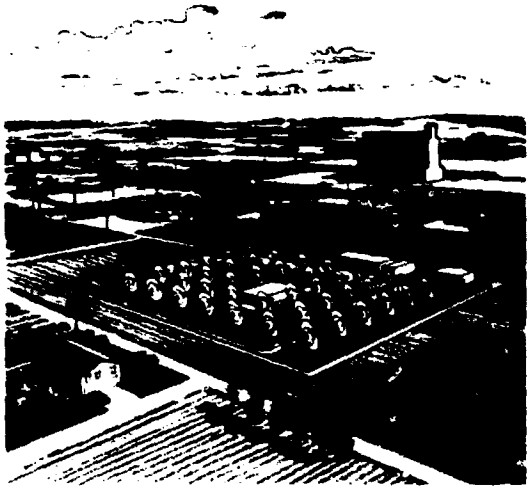


THE ELECTRICAL OUTPUT OF THE INDIVIDUAL GENERATORS IS COMBINED AND CONNECTED TO A UTILITY GRID

BRIEF DESCRIPTION OF PLANT

APPROXIMATELY 10 ACRE SITE WITH 65 PARABOLIC CONCENTRATORS, EACH 11 METERS IN DIAMETER AND EACH HAVING ITS OWN:

- RECEIVER
- ENGINE
- GENERATOR



THE ELECTRICAL OUTPUT OF THE INDIVIDUAL GENERATORS IS COMBINED AND CONNECTED TO A UTILITY GRID

BACKGROUND

- INITIATED IN MID 1977 WITH SYSTEM DEFINITION STUDY CONTRACTS
- ORIGINALLY ALL SMALL POWER SYSTEM TECHNOLOGIES WERE CONSIDERED
- PROGRAMMATIC CHANGES NARROWED PROJECT TO POINT FOCUSING DISTRIBUTED RECEIVER
- RESULTS OF RECENT TECHNICAL STUDIES FURTHER NARROWS CONCEPT TO DISTRIBUTED GENERATION (i.e., ENGINE AT FOCUS)

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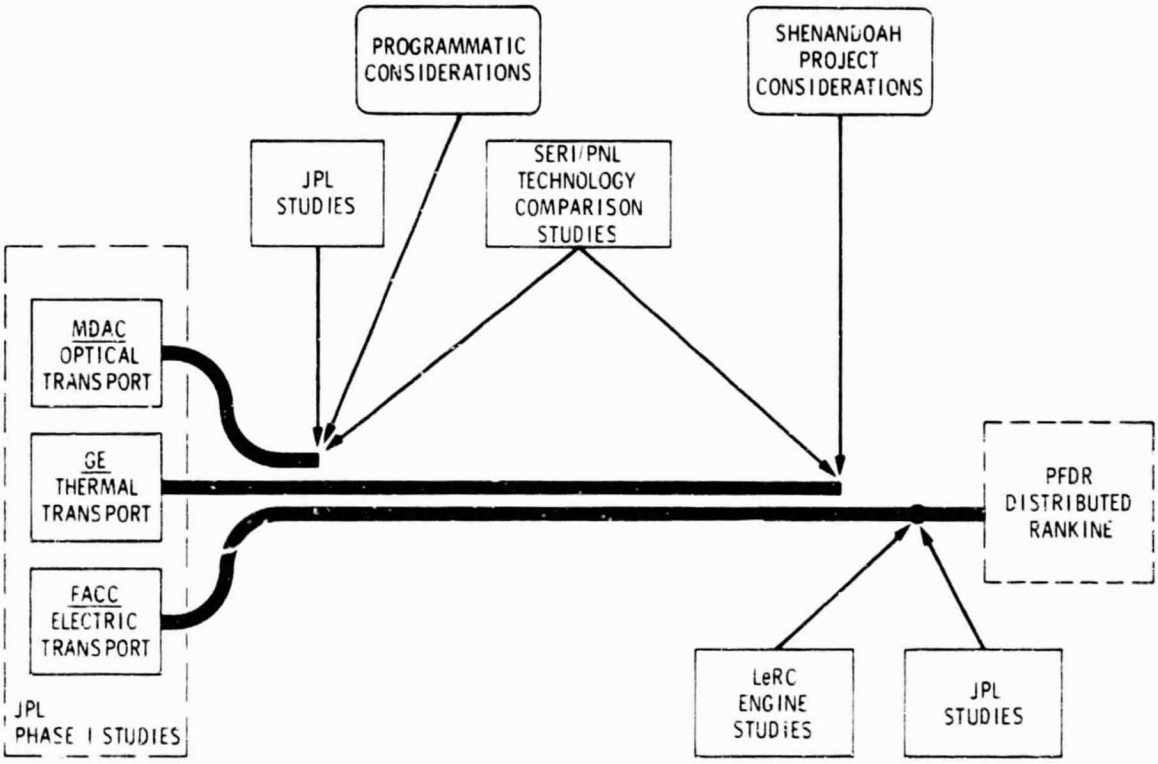
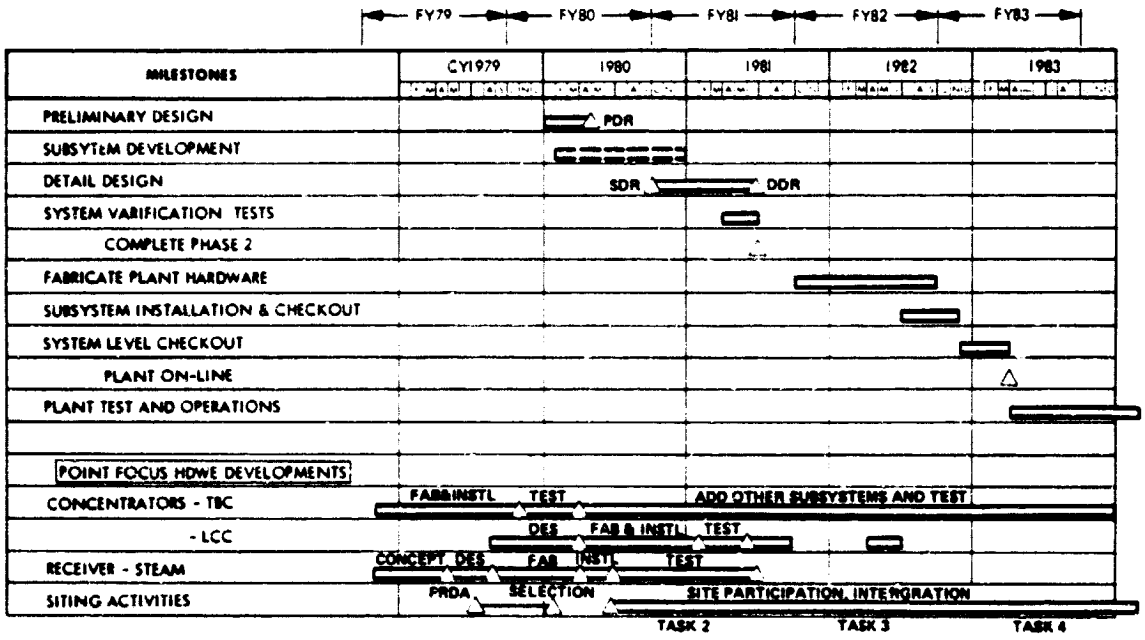
- RESULTS OF RECENT TECHNICAL STUDIES FURTHER NARROWS CONCEPT TO DISTRIBUTED GENERATION (i.e., ENGINE AT FOCUS)

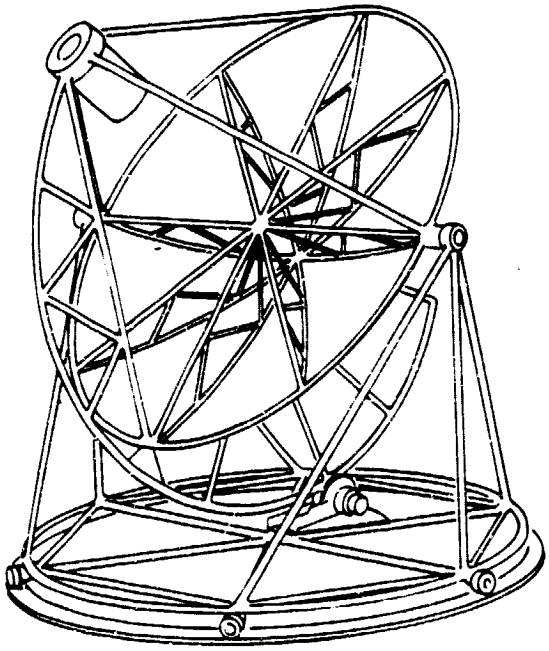
EVOLUTION OF TECHNICAL APPROACH



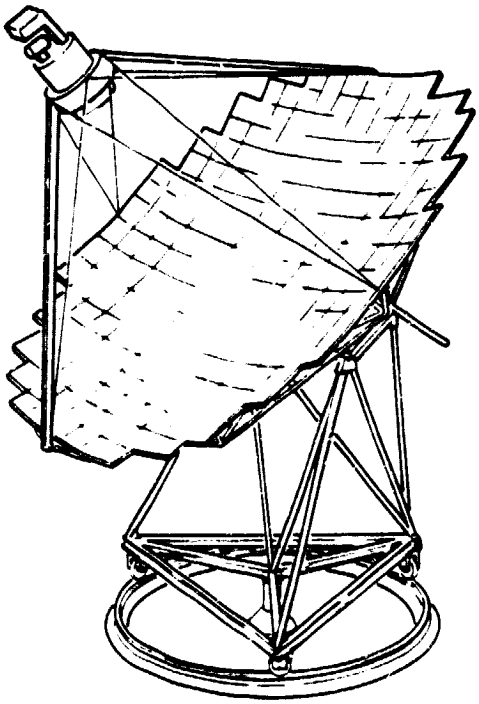
SMALL COMMUNITY SOLAR THERMAL POWER EXPERIMENT



LIKELY CANDIDATES FOR THE CONCENTRATORS ARE THE "LOW COST" AND "TEST BED" DESIGNS SPONSORED BY JPL TECHNOLOGY PROGRAMS

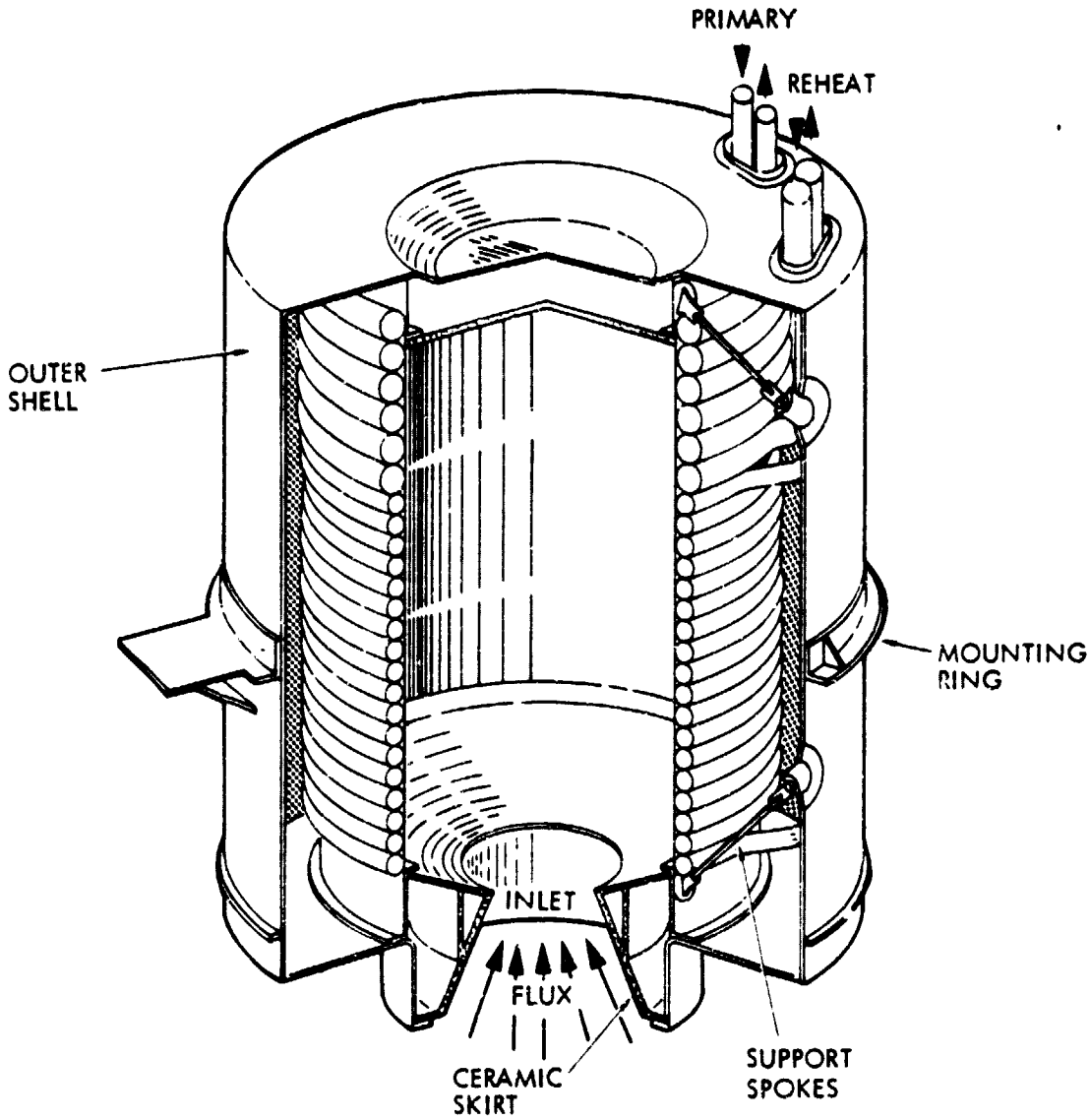


LCC

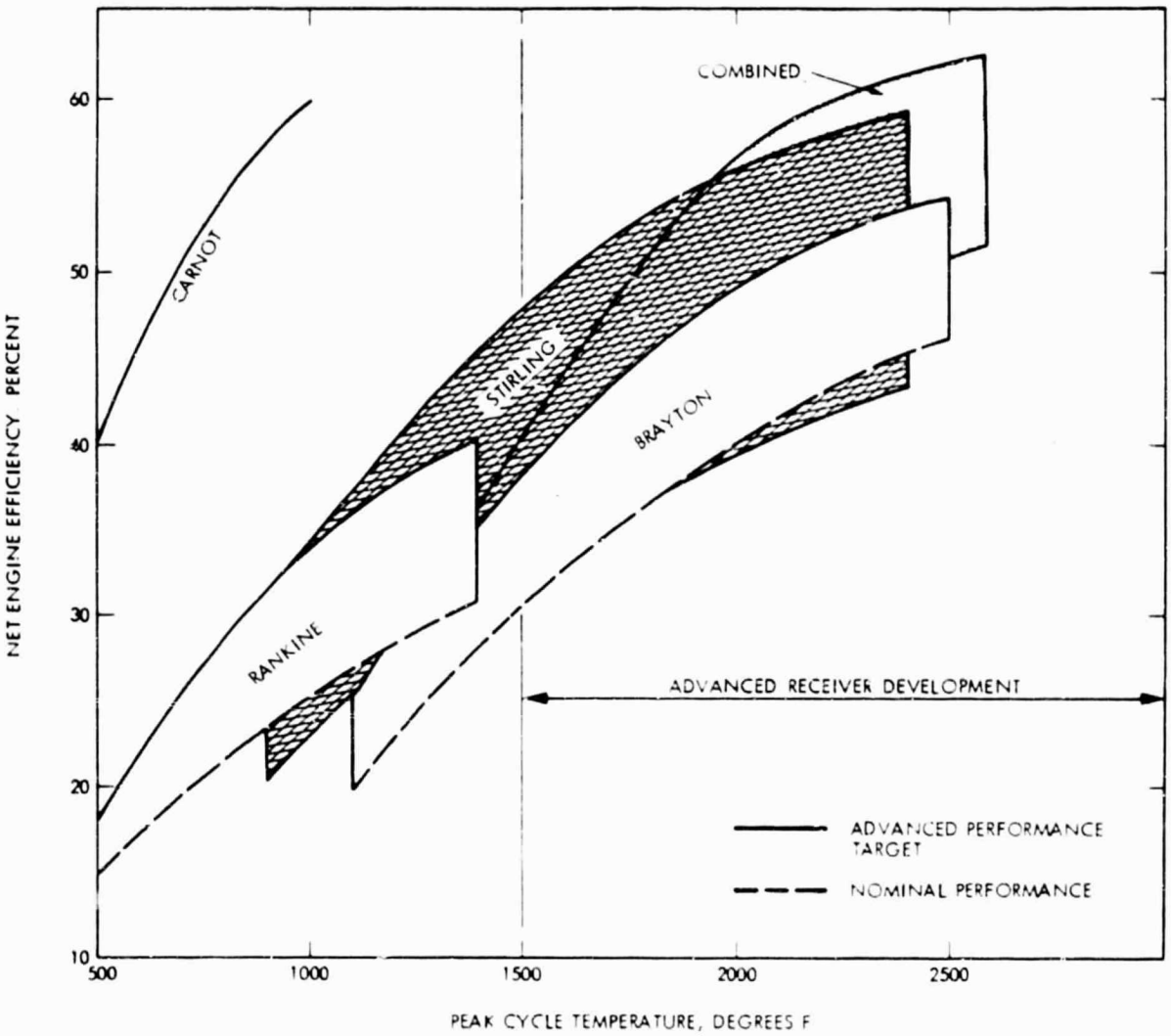


TBC

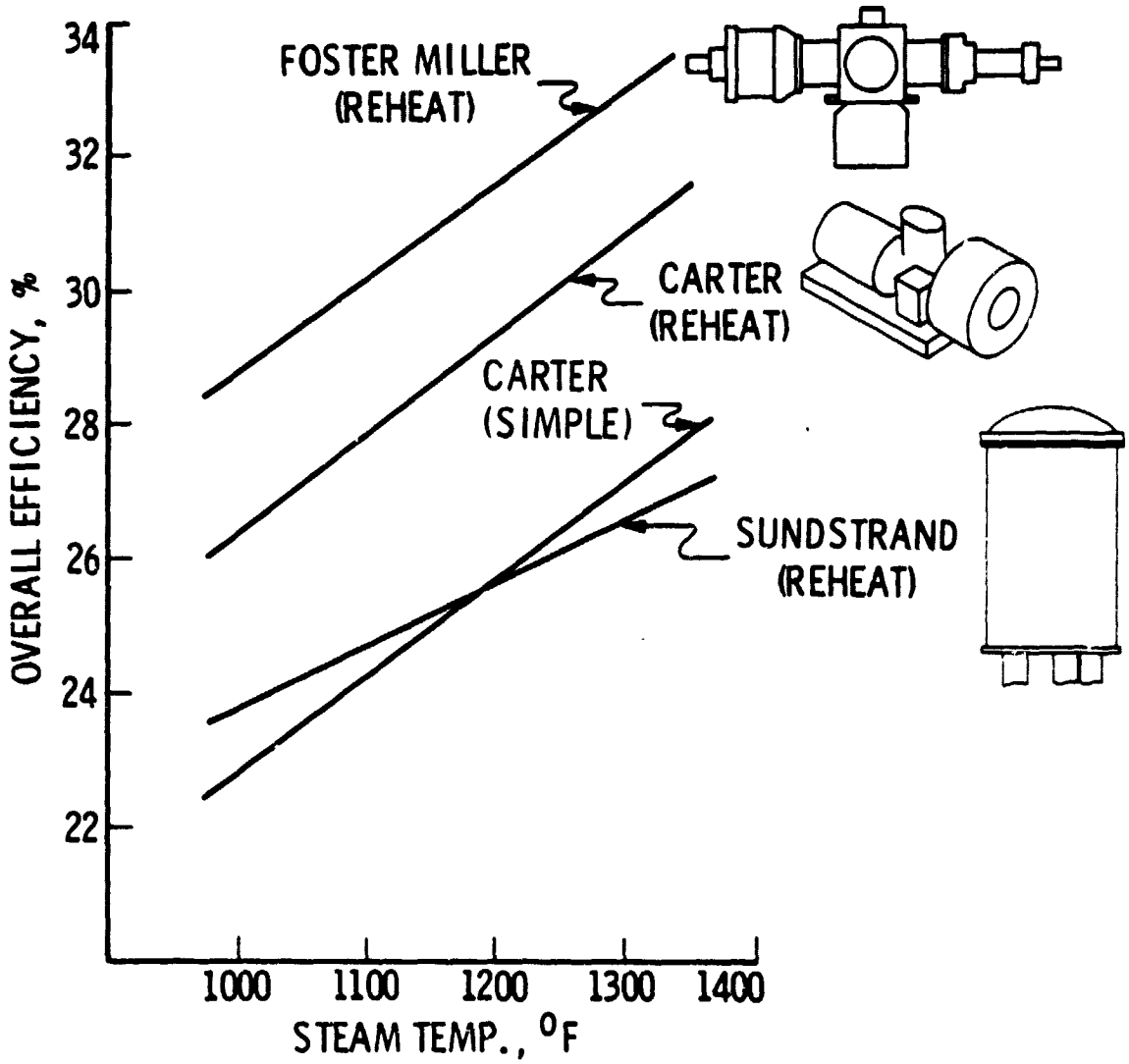
GARRETT CORPORATION IS DEVELOPING A STEAM RECEIVER AS PART OF THE JPL TECHNOLOGY DEVELOPMENT PROGRAM



COMPARISON OF ENGINE EFFICIENCIES



EFFECT OF TEMPERATURE ON PERFORMANCE (80kW THERMAL INPUT)



SITING ACTIVITIES

SELECT A SITE PARTICIPATION TEAM TO COMPLEMENT THE SYSTEM CONTRACTOR'S EFFORT IN PHASE III OF THE PROCUREMENT

- PROVIDE SITE, SITE DATA
- ACCESS ROADS, UTILITIES
- PERMITS, APPROVALS
- ELECTRICAL DISTRIBUTION INTERFACE
- SITE SUPPORT SERVICES

	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84
SITE ACTIVITIES							
SITE SELECTION		RFP	SELECT				
SITE PARTICIPATION			ACQUISITION, PREPARATION, OPERATION				
				TASK 2	TASK 3	TASK 4	

SITE AWARD CRITERIA AND REQUIREMENTS

- DISTINCT URBAN OR RURAL COMMUNITY (<100 MWe LOAD)
- TEAM SHOULD CONTAIN UTILITY, COMMUNITY ORGANIZATION
- COMPETENCE OF COMMUNITY/UTILITY TEAM
- OFFER OF SUITABLE 10 ACRE SITE
- GOOD INSOLATION RESOURCE
- MINIMUM STORM/FLOOD RISK
- MINIMUM REGULATORY PROBLEMS

The following questions were directed to and answered by Mr. Taras Kiceniuk, JPL:

Q. "Is the feed pump development considered to be state of the art at the operational pressures?"

A. "Yes, these engines have run and the controls have functioned at 1000°F. There are potential problems in the stability of operation which are connected with the feed pump and the monotube boiler. Perhaps the flow of feed water will have to be moderated through the use of multiple taps to sense the temperature at various points. Yet this is considered state of the art."

Q. "Excluding land costs, what is the community going to have to invest for the services it will have to provide?"

A. "An amount less than $300,000 has been estimated. This figure is only speculative, as is specific community involvement."

Q. "What is expected of the community during the follow-up?"

A. "After testing and evaluation of the installation the community will provide the operating personnel. In event that the system is automated this may only require a watchman."

Q. "Is there a storage system incorporated into this project?"

A. "No, it will operate only during the day since it includes neither storage nor a hybrid system."

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PARABOLIC DISH MODULE EXPERIMENTS

A PROGRAM REVIEW

Richard R. Levin
JPL

Louis Huang
USN

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This presentation gives an overview of the JPL Parabolic Dish Module Experiments. A general description of Point Focusing Distributed Receiver (PFDR) Technology and its key features will be followed by JPL's approach to PFDR development, a description of the JPL Engineering Experiments and a Description of the Parabolic Dish Module Experiments themselves.

C-21

PRESENTATION OUTLINE

- POINT-FOCUSING DISTRIBUTED RECEIVER (PFDR) TECHNOLOGY
- JPL APPROACH TO PFDR DEVELOPMENT
- JPL ENGINEERING EXPERIMENTS
- PARABOLIC DISH MODULE EXPERIMENTS

The goals of JPL's Engineering Experiments are threefold. A demonstration of the technical readiness of PFDR technology is only one. Demonstrations of the economic and the operational readiness of the technology must also be made before the experiments can be considered successful.

PFDR technology is able to provide thermal as well as electric power. Suitable experiments are being designed to test all aspects of the technology. These experiments must be completed and the results fully analyzed if the full potential of the PFDR concept is to be realized.

GOAL

DEMONSTRATE

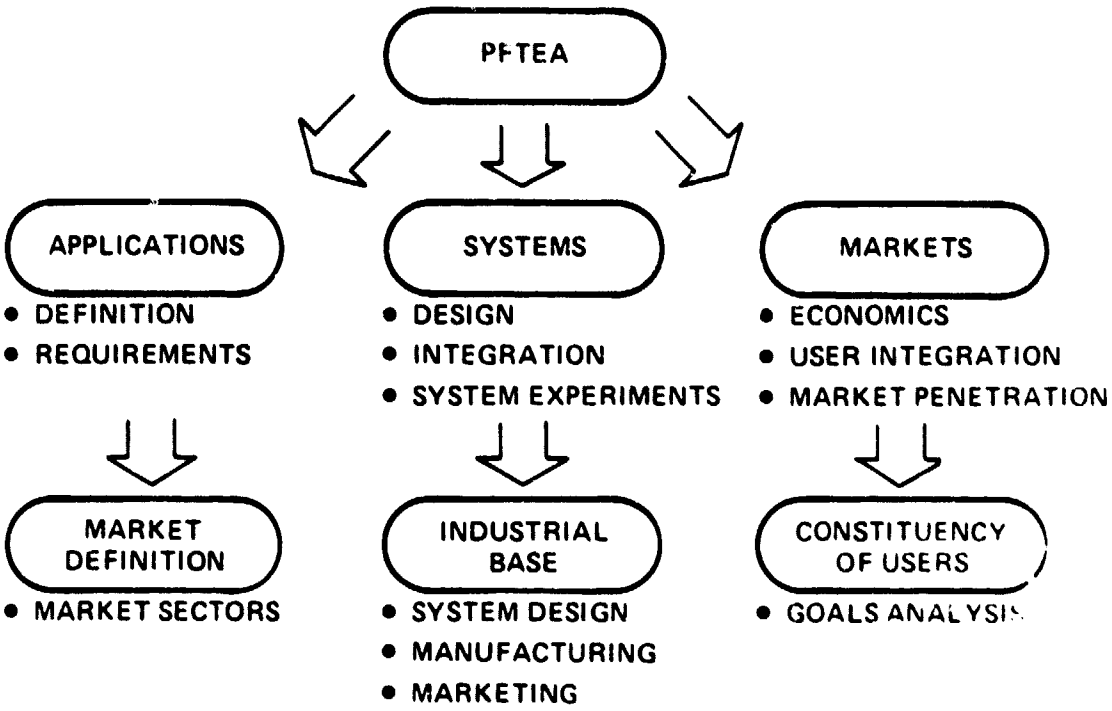
- TECHNICAL
- ECONOMIC
- OPERATIONAL

READINESS

OF PFDR TECHNOLOGY FOR ELECTRIC AND THERMAL POWER APPLICATIONS

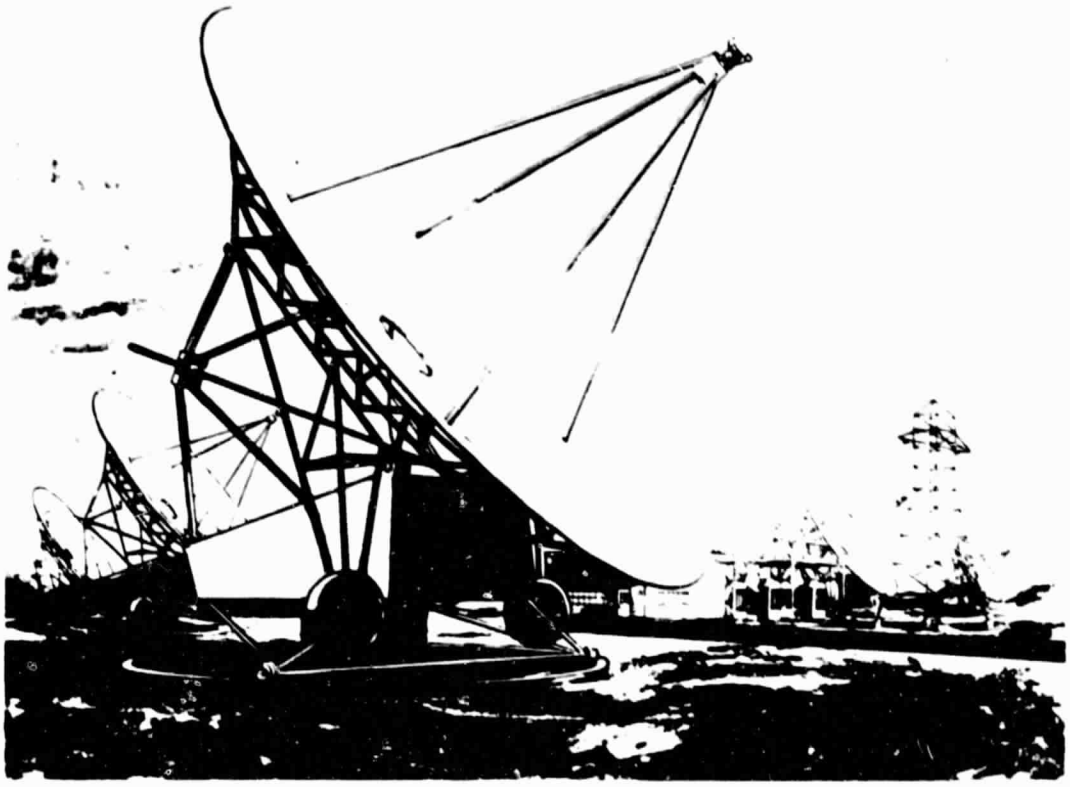
The Point Focusing Thermal and Electric Application (PFTEA) Project is one of three complementary solar thermal power projects at JPL. The actual solar thermal power systems to be tested are integrated and deployed by PFTEA considering the potential markets for such systems and the applications which they will see. This approach builds confidence in the experimental results and addresses technical, economic and operational issues, the three essentials of any experiment.

PRODUCTS


PFTEA
APPLICATIONS
• DEFINITION
• REQUIREMENTS
SYSTEMS
• DESIGN
• INTEGRATION
• SYSTEM EXPERIMENTS
MARKETS
• ECONOMICS
• USER INTEGRATION
• MARKET PENETRATION
MARKET DEFINITION
• MARKET SECTORS
INDUSTRIAL BASE
• SYSTEM DESIGN
• MANUFACTURING
• MARKETING
CONSTITUENCY OF USERS
• GOALS ANALYSIS

PFDR technology employs parabolic dish reflectors to concentrate and focus solar energy on a receiver located at the focal point of the dish. Optical transmission losses in these systems are small. The non-ideal reflective characteristics of the concentrator and re-radiation of energy of the receiver are the principal causes of energy loss from these systems.

The solar energy absorbed by the working fluid circulated through the receiver can be used directly as industrial or process heat, or the energy can be used to drive a heat engine allowing conversion to mechanical or electrical power. Brayton, Rankine or Stirling cycle machines can be employed, and conversion to electric power accomplished by the inclusion of an alternator in the package.



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OF POOR QUALITY

PFDR technology, by employing two-axis tracking and high concentration ratios, can achieve high conversion efficiencies. The energy collected can be converted to serve thermal or electric loads. Split fields are feasible if a combination thermal and electric load is served.

PFDR technology offers all the advantages of a modular system. Interchangeability and mass producibility of components are advantages which can reduce the lifetime cost of ownership of these systems. The use of PFDR modules as system building blocks can reduce the capital-intensive character of power plant construction and can mean new flexibility in plant design and growth.

WHY PFDR TECHNOLOGY

- TWO-AXIS TRACKING
- HIGH CONCENTRATION → HIGH TEMPERATURE → HIGH CONVERSION EFFICIENCY
- ELECTRIC TRANSPORT AND/OR THERMAL TRANSPORT
- MODULAR – MASS PRODUCIBLE
- BRAYTON, RANKINE, STIRLING CYCLE TECHNOLOGY

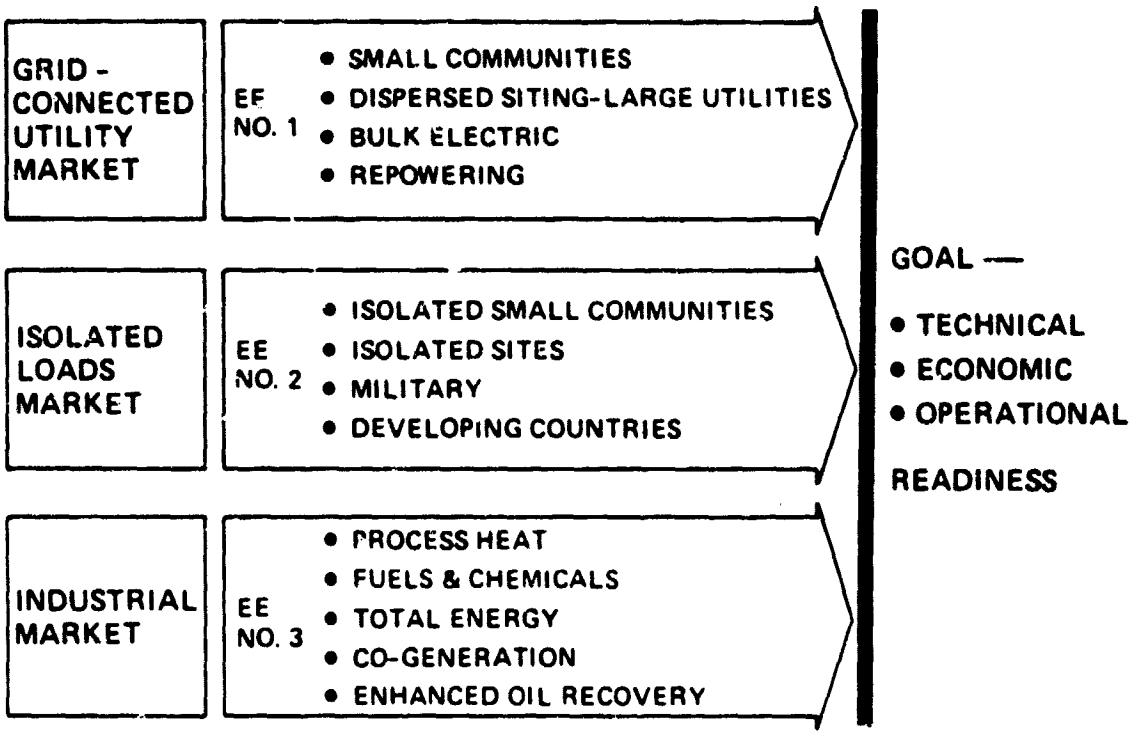
JPL's Engineering Experiments recognize three distinct markets. One series of engineering experiments is devoted to each.

The Small Community Solar Thermal Power Experiment (SCSE) has been described. The second set of experiments, the Parabolic Dish Module Experiments (PDME), addresses the isolated load market sector and includes those applications not directly served by a large utility grid. Isolated sites, military applications and developing countries are typical examples.

The third set of experiments addresses the industrial market and, in addition to process heat, includes more advanced concepts. EE No. 3 planning is preliminary at this time.

PFDR DEVELOPMENT

APPROACH



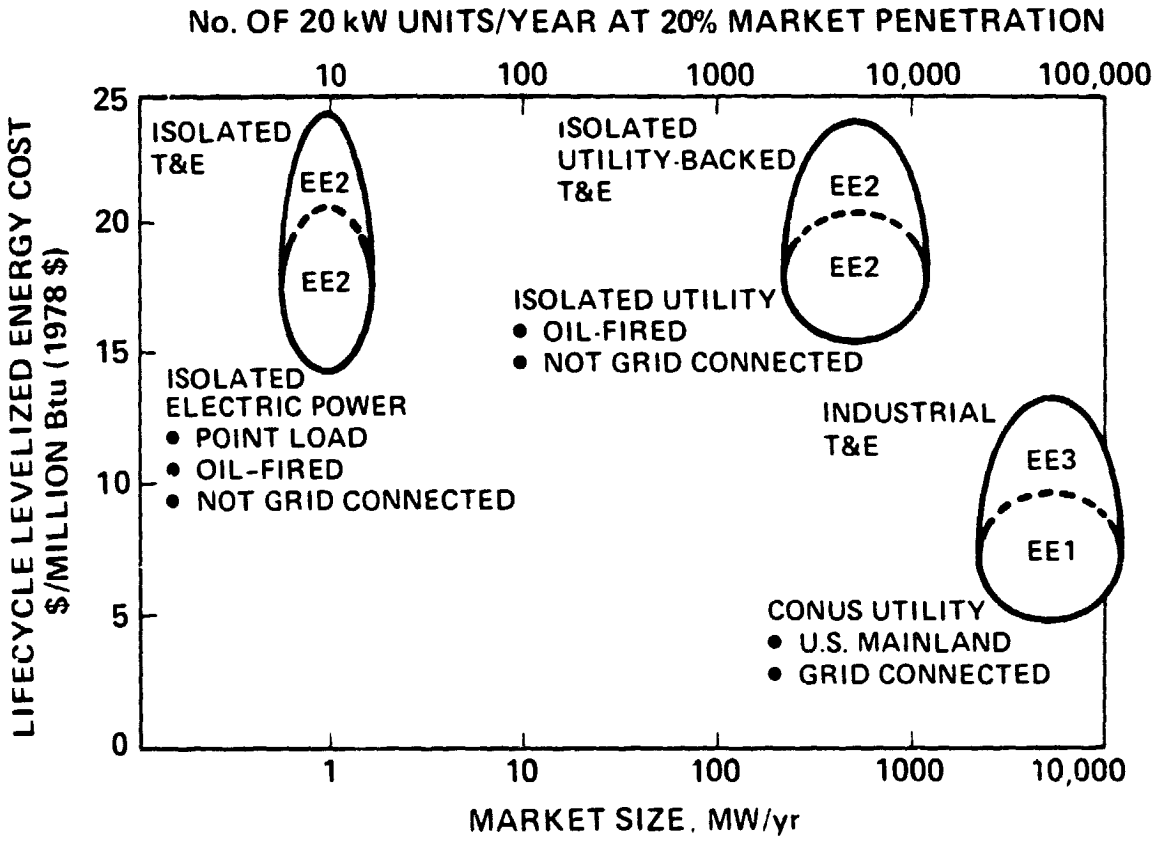
The partitioning of the Engineering Experiments by market sector is illustrated again when estimated life cycle energy cost is plotted against market size.

EE No. 1 and No. 3 address the larger, lower cost markets whereas EE No. 2 addresses the higher cost, lower volume applications. All sectors must be addressed if the full potential of the PFDR technology is to be measured.

ENGINEERING EXPERIMENTS

ENERGY COST AND MARKET SIZE

1990 - 2000



The Parabolic Dish Module Experiments (PDME) will be deployed in the 1983-1986 time period and will test several power generation technologies in appropriate experiments. The scale will be small (100-200KWe) to permit full evaluation of the technical concept for modest investments.

A key feature of these experiments is the early involvement of the users through a co-funding arrangement. Users and system integrators are brought together early in the planning stage and work together during the development of the experimental power plants. An important by-product of this approach is the establishment of an industrial base for the manufacture of PFDR technology hardware.

PARABOLIC DISH MODULE EXPERIMENTS

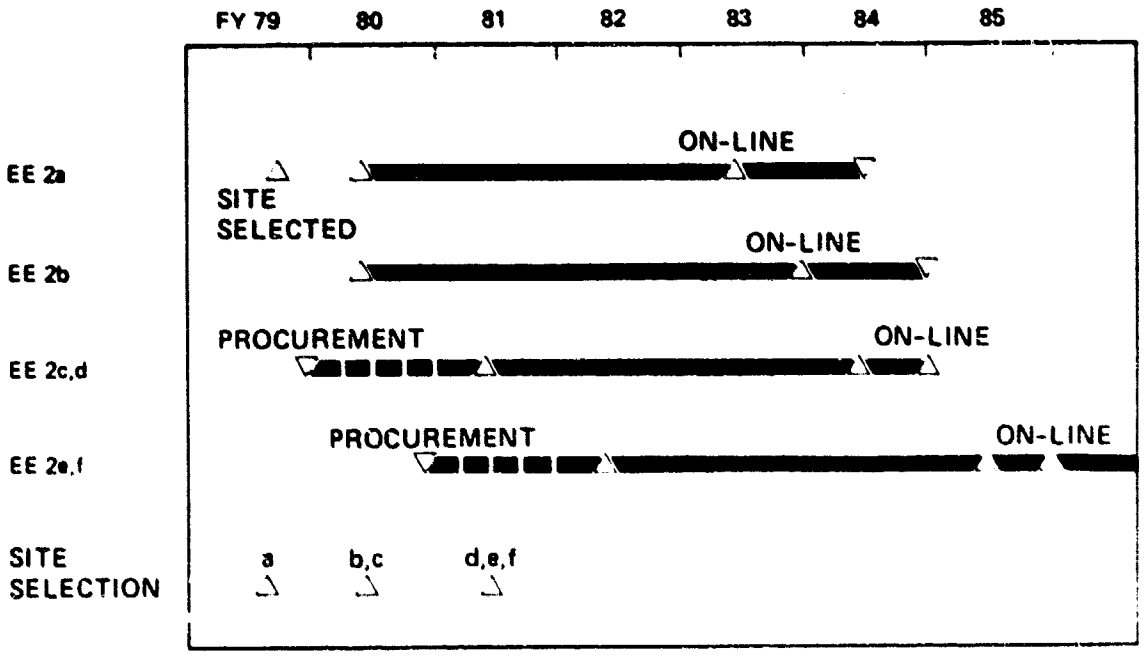
- **APPROACH**
  - DEVELOP AND DEPLOY A NUMBER OF SMALL-SCALE ENGINEERING EXPERIMENTS ($\approx$ 100 kWe) IN SELECTED APPLICATION ENVIRONMENTS
  - REQUIRE SUBSTANTIAL CO-FUNDING – INVOLVE USERS
  - USE STATE-OF-THE-ART PFDR TECHNOLOGY
  - ESTABLISH INDUSTRIAL SYSTEM DESIGN AND INTEGRATION CONTRACTORS

A baseline schedule for the deployment of six Parabolic Dish Module Experiments is shown. Phased starts are important to allow evolution of the hardware and to permit program flexibility. Sites will be selected early in each experiment planning cycle. This will permit the users of these systems to become involved in experiment planning and hardware integration.

PARABOLIC DISH MODULE EXPERIMENTS

SCHEDULE

FOR SIX EXPERIMENTS



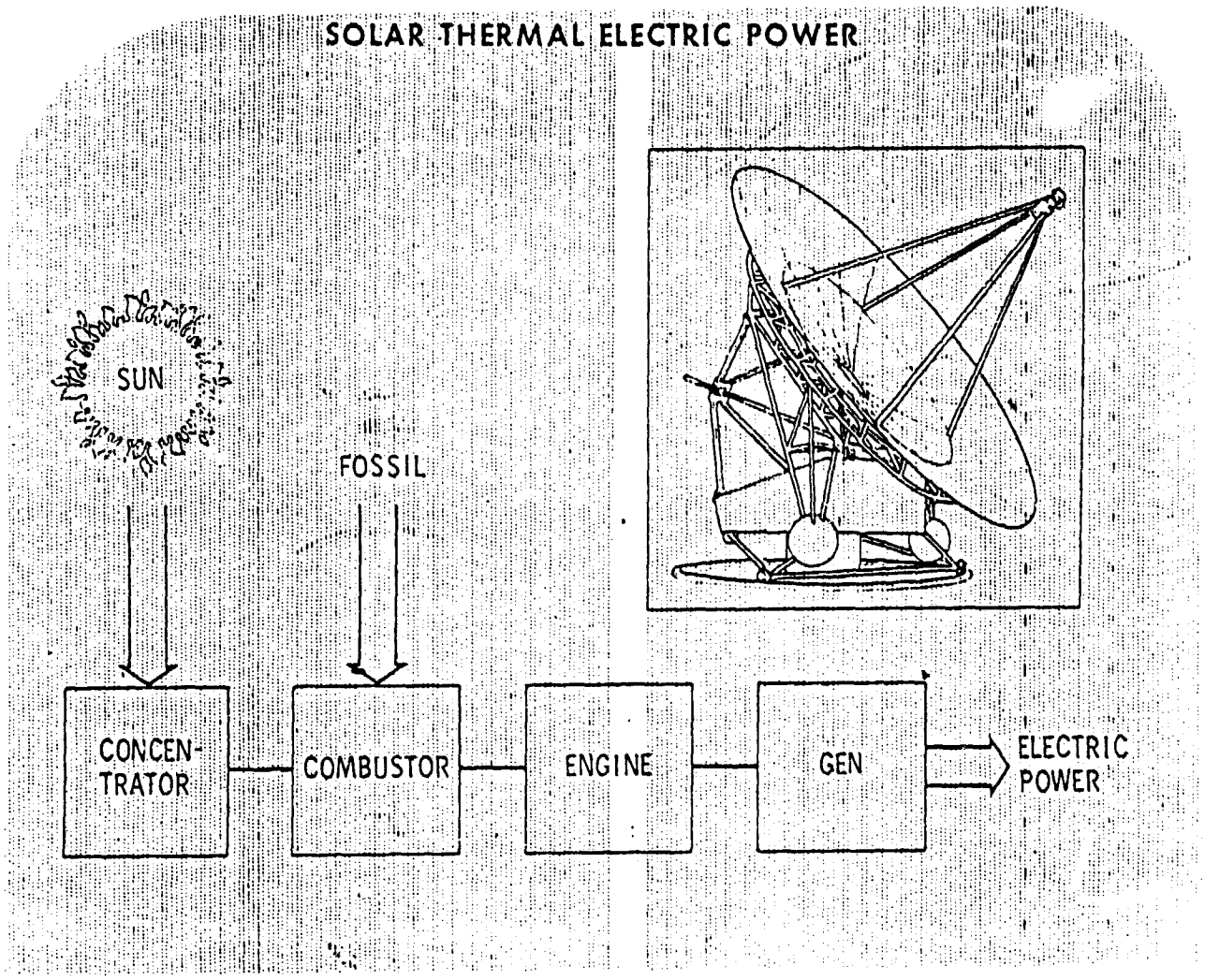
The first Parabolic Dish Module Experiment will be a 100-120 KWe plant co-funded by the U.S. Navy through the Civil Engineering Laboratory. It will generate electrical power using medium performance Brayton cycle energy conversion (1500-1600°F). Individual module power outputs will be combined and conditioned to produce the rated power at 480V, 30, 60Hz.

In order to earn capacity credit for the plant, there will be three operational modes:

solar - all power derived from insolation

hybrid - power derived from insolation and fossil fuel

fossil - all power derived from fossil fuel


SOLAR THERMAL ELECTRIC POWER
SUN
FOSSIL
CONCEN-
TRATOR
COMBUSTOR
ENGINE
GEN
ELECTRIC
POWER

Hybridization has been selected by JPL as the best method of ensuring capacity credit for the early Parabolic Dish Module Experiments. Clear advantages exist in the near term over storage systems. Both early plant deployment and lower experiment costs will accrue. As storage technology matures and system costs are reduced, these systems can be used to supplement or replace the hybridizing fossil fuel technology. This approach permits both solar thermal power technology and storage technology to develop independently.

HYBRIDIZATION IMPACTS

ADVANTAGES	DISADVANTAGES
CAN PROVIDE UP TO 100% PLANT CAPACITY CREDIT FOR SOLAR PLANTS	
AVOIDS PRESENT HIGH COSTS OF DEVELOPING AND INCORPORATING STORAGE SYSTEMS	IMPOSES FUEL AND COMBUSTOR COSTS
REMOVES PERFORMANCE PENALTIES AND RISKS IMPOSED BY STORAGE SYSTEMS	IMPOSES FOSSIL FUEL SYSTEM PERFORMANCE PARAMETERS
ALLOWS EARLIER DEPLOYMENT OF EXPERIMENTS	DEVELOPMENT WORK REQUIRED FOR HYBRID COMBUSTORS AND CONTROLS
LESS SEVERE ENVIRONMENTAL IMPACTS THAN FOR PURE FOSSIL PLANTS	REQUIRES CONSUMPTION OF SOME FOSSIL FUEL WITH ASSOCIATED ENVIRONMENTAL IMPACTS
ALLOWS PLANT OPERATION OVER A VARIETY OF LOAD CONDITIONS AND INSOLATION LEVELS	COMBUSTORS MUST BE DEVELOPED WHICH OPERATE OVER A WIDE RANGE OF THERMAL POWER LEVELS

The system integration contract award for the first Parabolic Dish Module Experiment (EE No. 2a) will be made by mid-April, 1980. Site selection for this experiment is also proceeding and will be resolved by the end of 1979.

The second experiment (EE No. 2b) is now being planned. Funding availability will dictate the timing of this experiment.

Both experiments will use hybridized Brayton cycle energy conversion employing JPL developed concentrator, receiver and engine.

PARABOLIC DISH MODULE EXPERIMENTS

STATUS

- **EE 2a**
  - U.S. NAVY (CIVIL ENGINEERING LABORATORY) COFUNDED
  - 100 kW MODULAR, MOVABLE POWER PLANT USING PFDR HYBRID BRAYTON TECHNOLOGY
  - RFP FOR SYSTEM DESIGN AND INTEGRATION TO BE ISSUED 4th QUARTER FY 79
  - SITE SELECTION PRDA IN PREPARATION
- **EE 2b**
  - APPLICATION TO [illegible] SELECTED VIA COMPETITIVE SITE PROCUREMENT
  - WILL USE PFDR HYBRID BRAYTON TECHNOLOGY
  - RFP FOR SYSTEM TO BE ISSUED 4th QUARTER FY 79

The JPL Engineering Experiments are designed to demonstrate the technical economic and operational readiness of point focus distributed receiver technology. Small experiment size and maximum versatility are key features of the experiments.

Both Brayton and Stirling cycle energy conversion techniques will be tested in the Parabolic Dish Module Experiments. Phased starts ensure that knowledge gained in the early experiments will improve later designs and the completeness of the test programs.

SUMMARY

- JPL HAS EXTENSIVE APPLICATION EFFORT UNDERWAY
- SMALL-SCALE EXPERIMENTS CAN SATISFY MOST OF THE TECHNOLOGY AND ENGINEERING DEVELOPMENT/DEMONSTRATION OBJECTIVES WITHOUT EXCESSIVELY LARGE INVESTMENTS
- PRESENTED OVERVIEW OF COMPLEMENTARY PROGRAMS AT JPL COVERING
    - GOALS
    - PRODUCTS
    - TECHNOLOGY
    - EXPERIMENTS

The following questions were directed to and answered by Dr. Richard Levin, JPL:

Q. "The tracking and drive systems have not been mentioned. Are they included in the RFPs or experiments?"

A. "Our technology project is developing the components. For example, the tracking controls and drive mechanisms are considered to be part of the concentrator. The receiver will be built by a separate corporation."

Q. "Are both EE1 and EE2a going to use the GE concentrator?"

A. "Yes, it appears to have the lowest cost and greatest performance payoff."

Q. "What is the cost of this project?"

A. "The total experiment (EE2) from beginning to end will cost about five million dollars."

Comment

"The multi-fuel capacity of these systems has many merits. Perhaps one application that should be explored is the use of these systems in areas where insolation is not very great, or where alternate fuel (biomass, fossil fuel, etc.) is cheap and readily available. When sunlight is available it, of course, can be utilized. Yet by having some other fuel as the primary source, the problem of electrical storage is eliminated. Perhaps it would be wise, therefore, to conduct one of these experiments in an area where these conditions exist."

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Response

"This proposal is indeed creditable, yet there are certain problem areas that must be dealt with. The main problem would be in combusting solid fuels. As the system is now, liquid fuels are easily piped to the combuster unit. To handle solid fuels, the combuster would have to be relocated, or other measures taken to feed heat to the unit."

Comment

"The current engine design is only capable of burning liquid fuels or natural gas. An additional heat exchanger is needed to utilize solid fuels. This would increase cost and weight and would decrease efficiency. Later, modifications are planned to include solid fuel capability."

Q. "Six experiments have been listed yet only two described. Is this due to lack of funds?"

A. "The experiments are operating on a nominal schedule, but there is another reason for this. The experiments are not all starting at the same time so that experience learned from the first ones can be applied to later experiments. In this manner, the last experiments will be much more sophisticated and efficient, leading to a higher payoff."

Q. "Will the initial RFP be for selecting the sites for all six experiments?"

A. "At least two RFPs are expected. In the case of the Navy experiment, the site is already determined, so no RFP is necessary."

Q. "Have engineering studies determined the loss in efficiency brought about by placing the engine at some point on the collector other than at the focal point?"

A. "Actual experimental calculations have not been done, but the overall concepts have been considered."

Comment

"Some studies have been done concerning the changes mentioned. There is little advantage gained by reducing the structural weight at the focal point even by a factor of two. Most of the critical loading on the dish itself concerns the overturning moment of the wind load. Relocating the engine will not decrease the cost per square meter of the concentrator by an appreciable amount. Since the working fluid is at extremely high temperatures, the tradeoffs involved seem to make engine relocation an unwise decision."

Q. "How many dishes will be used in this experiment?"

A. "There will be six dishes for a total of 100KW in the first experiment. This will not be enough to determine actual manufacturing costs, to answer another question. These are purely engineering experiments, not commercialization or manufacturing analyses. Production costing is being done, but it is independent."

IMPLEMENTATION

DOD PROJECT MANAGER-
MOBILE ELECTRIC POWER
COL A. ROWE

MANDATE

- ORDER OUT OF LOGISTICS CHAOS

MISSION

- MINIMIZE MAKES & MODELS OF MOBILE ELECTRIC POWER SOURCES
- MAXIMIZE USE OF STANDARD MOBILE ELECTRIC POWER SOURCES
- PROVIDE AGGRESSIVE MANAGEMENT IN TECHNICAL, LOGISTICS & PROCUREMENT AREAS

MOBILE ELECTRIC POWER
TASK LIST

TASK	DATE ASSIGNED	AUTHORITY	CURRENT STATUS
DOD			
ESTABLISH AND MAINTAIN DOD FAMILY OF MEP SOURCES	1 JULY 67	CHARTER, DOD DIRECTIVE	CONTINUING
ARMY			
MANAGE ARMY MEP ENGINEERING DEVELOPMENT	18 AUG 67	LTR, DEP CG, DARCOM	CONTINUING
OTHER			
PLAN AND COORDINATE THE DOD DEVELOPMENT & PRODUCT IMPROVEMENT EFFORT ON MEP SOURCES	2 OCT 74	CHARTER, DOD DIRECTIVE	CONTINUING

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STANDARDIZATION

- MILITARY STANDARDS

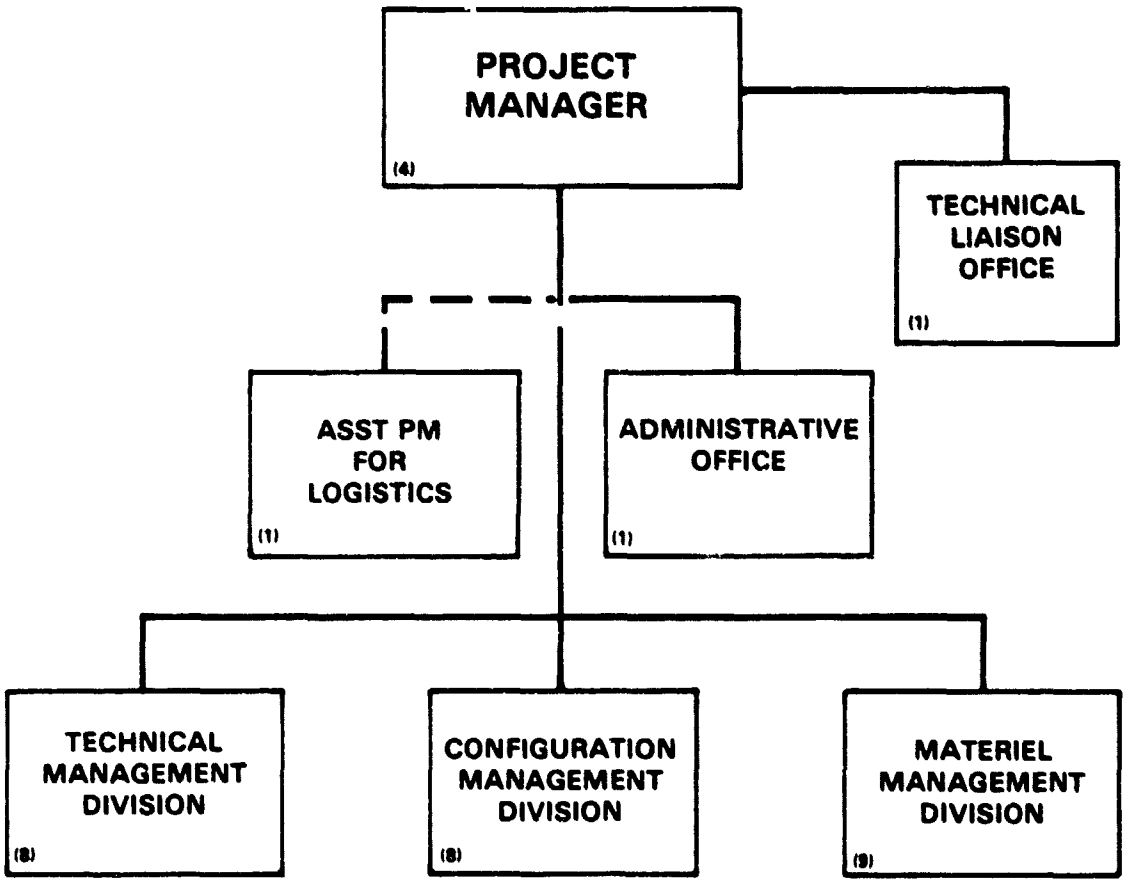
  633
  1650
  1332

- DOD STANDARD FAMILY

- DEVIATIONS

- POLICY
- CONTROL

PROJECT ORGANIZATION



CONFIGURATION MANAGEMENT

FUNCTIONAL BASE LINES

7 PURCHASE DESCRIPTIONS
4 MILITARY SPECIFICATIONS

PRODUCT BASE LINES

1 PURCHASE DESCRIPTIONS
5 MILITARY SPECIFICATIONS
31 TECHNICAL DATA PACKAGE (TDP's)

CM ACTIVITY

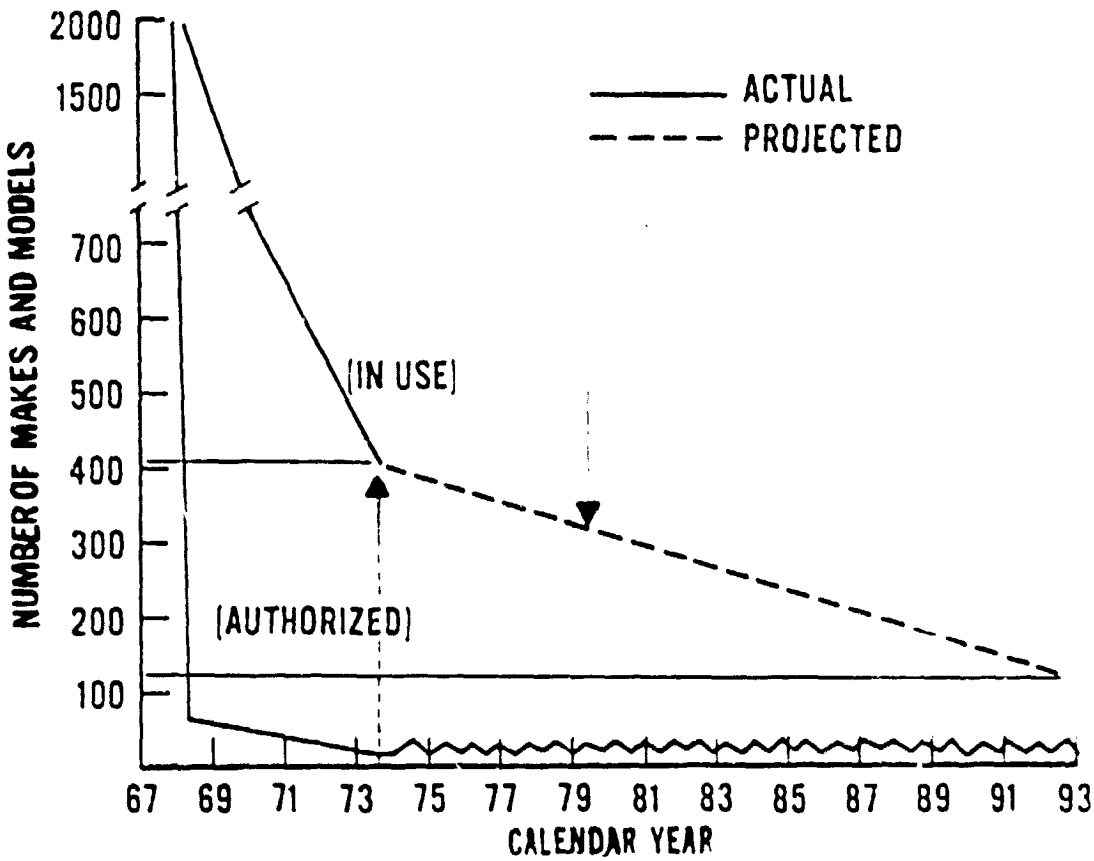
17 CONTRACTS
* 83 ECP's/RFD's/RFW
78 APPROVED

* CLASS 1 ECP's & MAJOR RFD's/RFW's

FUNCTIONS

- STANDARDIZATION
- PROCUREMENT
- CONFIGURATION MANAGEMENT
- QUALITY ASSURANCE
- READINESS
- TECHNICAL CONSULTATION
- RESEARCH–DEVELOPMENT–NEW EQUIPMENT TECHNOLOGIES

DOD MOBILE ELECTRIC POWER SOURCES



MANAGEMENT APPROACH OF MEP PROJECT

- USE EXISTING SERVICE/DSA STAFFS AND PROCEDURES WHERE POSSIBLE
- ESTABLISH A DOD FAMILY WITH HIGH DEGREE OF COMMONALITY
- CONFIGURATION MANAGEMENT CONTROL AT PROJECT LEVEL
- OBTAIN DATA SUITABLE FOR PROCUREMENT OF IDENTICAL ITEMS
- CHALLENGE TECHNICAL REQUIREMENTS
- CHALLENGE EACH REQUEST FOR A SPECIAL PURPOSE POWER SOURCE
- USE R&D PROGRAM FOR CONTROLLED EVOLUTION OF DOD FAMILY

QUALITY ASSURANCE

OVERALL COGNIZANCE - PM-MEP

FUNCTIONAL ACTIVITY

- ARMY - DARCOM
  MERADCOM
  TSARCOM
- AIR FORCE -AFLC
  SM-ALC
- NAVY -NAVAIR
  NAEC
- DLA -DCAS
  DCSMA

DOD STANDARD FAMILY-MOBILE ELECTRIC POWER

	PRECISE		UTILITY		
KW RATING	60 HZ	400 HZ	60 HZ	400 HZ	28V DC
0.5			G	G	G
1.5			G,(FC)		G,(FC)
3			G	G	G
5			G,D	G	
10			G,D,(T)	G,D	T
15	D	D	D		(D*)
30	D	T,D,D*#	D		
60	D	T,D,T*	D		
72AC/21DC		D*			
72		D#			
100	D	D	D		
200	D				
500			D,D		
750 PRIME			D,T		

G-GASOLINE ENGINE DRIVEN
( )-IN DEVELOPMENT
FC-FUEL CELL

D-DIESEL ENGINE DRIVEN
*-GROUND SUPPORT

T-GAS TURBINE ENGINE DRIVEN
#-PLANNED DEVELOPMENTS

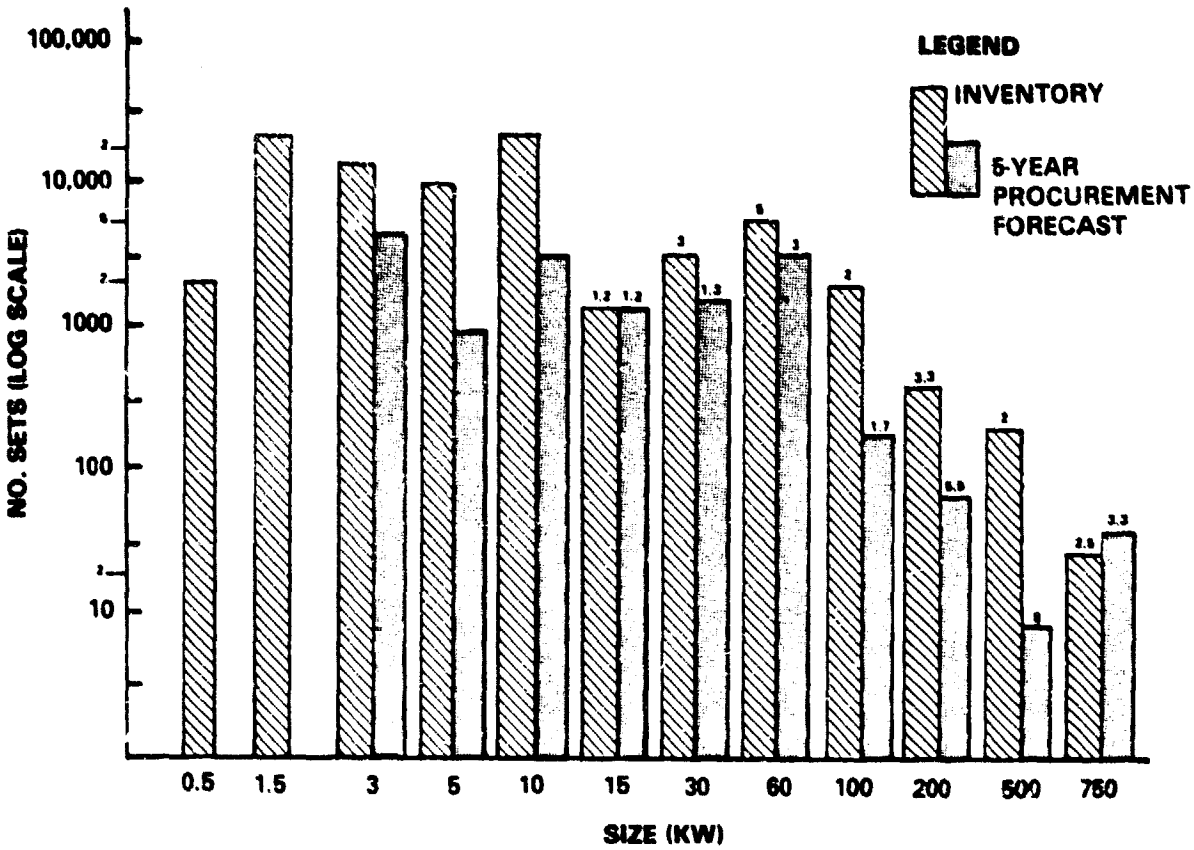
LATEST RATES FOR REPORTABLE GENERATOR SETS

	OR (%)
5 KW, 60 Hz TU	98
10 KW, 60 Hz TU	99.4
15 KW, 60 Hz TU	94.8
15 KW, 400 Hz TP	100
30 KW, 60 Hz TU	86.7
30 KW, 400 Hz TP	100
60 KW, 400 Hz TP	89.4
60 KW, 60 Hz TU	90.1
100 KW, 60 Hz TP	75.3
100 KW, 60 Hz TU	90.9

SHORTFALLS

- INABILITY TO OBTAIN REQUIREMENT DOCUMENTS
- LOW PRIORITIES/FUNDING
- TIME REQUIRED TO INTRODUCE NEW EQUIPMENT
- SYSTEM DEVELOPERS NOT DESIGNING FOR USE OF DOD STANDARD SETS

DOD MEP INVENTORY AND 5 YEAR PROCUREMENT FORECAST



TECHNICAL CONSULTATION

- ALL SERVICES/DOD AGENCIES
- MAJOR SUBORDINATE COMMANDS
  - TECHNICAL ADVISE TO CUSTOMERS

• XM1-M60	- 10 KW, 28 VDC, GTED (APU)
• PATRIOD	- 60 KW, 400 Hz AND 150 KW, 400 Hz GTED (RECAP)
• FIREFINDER	- 10 KW, 400 Hz, GTED
• PERSHING II	- 30 KW, 60 Hz, GTED (RECAP)
• BLACKHAWK	
• CH-47	TRICAPABILITY GPU (PNEUMATIC, HYDRAULIC, ELECTRIC)
• AAH	
• ROLAND	- COMPONENTS FROM 15 KW DED SET
• SATCOM	- 500 KW, DED
• TACFIRE	- 15 KW, DED

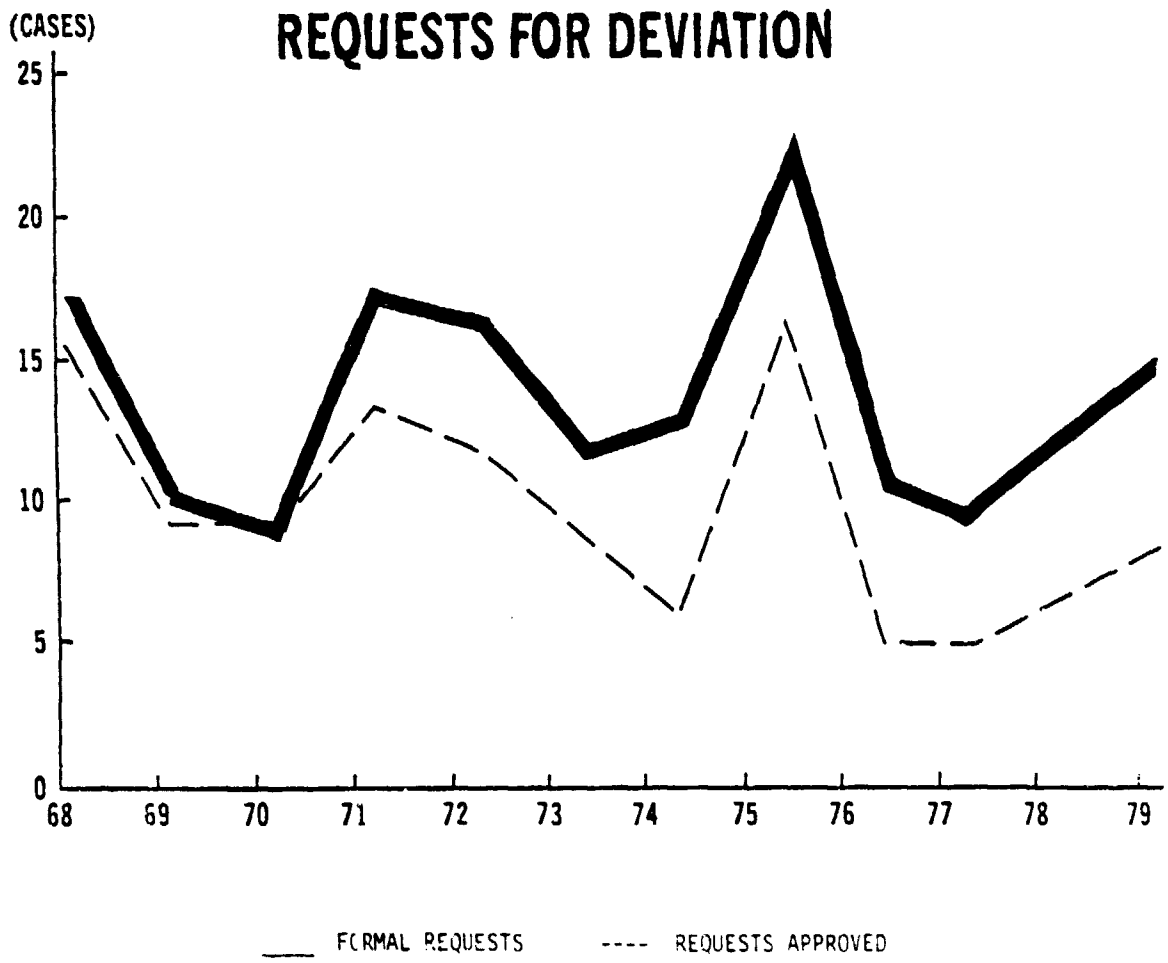
- OTHER MAJOR COMMANDS

SUMMARY

- PROGRAM FUNCTIONING AS INTENDED
- STANDARDIZATION PAY-OFF
- FAMILY NEEDS REVITALIZATION (FUTURE TECHNOLOGY)
- DEVELOPERS ON BOARD EARLIER
- PROCUREMENT PRIORITIES/FUNDING SUPPORT
- ENERGY OPPORTUNITIES

QUALITATIVE COMPARISON OF
MOBILE ELECTRIC GENERATING SOURCES

	MORE FAVORABLE				LESS FAVORABLE
COST/KW	GED--FC----------		DED----------		GTED
WEIGHT/KW	GTED----------	FC----------			DED
FUEL CONSUMPTION/KW	FC--------	DED-------	GED----------		GTED
RELIABILITY	FC----------		DED-------	GTED-----	GED
FUEL FLEXIBILITY	GTED--FC(HC)-------		DED-----	GED--------	FC(METH)
INDUSTRIAL BASE	DED------	GED-----	GTED----------		FC
NUMBER OF PARTS	FC---GTED----------			DED----------	GED
NOISE	FC----------			GED-----	GTED------ DED


REQUESTS FOR DEVIATION
(CASES)
25
20
15
10
5
0
68
69
70
71
72
73
74
75
76
77
78
79
FORMAL REQUESTS
REQUESTS APPROVED

MANUFACTURERS AND PRODUCTION IMPLEMENTATION

OF SMALL SOLAR THERMAL/ELECTRIC POWER SYSTEMS

James J. Connolly

Chairman, Solar Thermal Energy Division

Solar Energy Industries Association

OBJECTIVES

- INTRODUCTION TO SEIA AND THE SOLAR THERMAL DIVISION
- INDUSTRY VIEWS OF PRODUCT DEVELOPMENT
- INDUSTRY LOOK AT POINT FOCUS THERMAL TECHNOLOGY
  - COMPONENTS
  - SYSTEMS
- INDUSTRY PROPOSALS FOR ESTABLISHING MANUFACTURING AND PRODUCTION ENVIRONMENT

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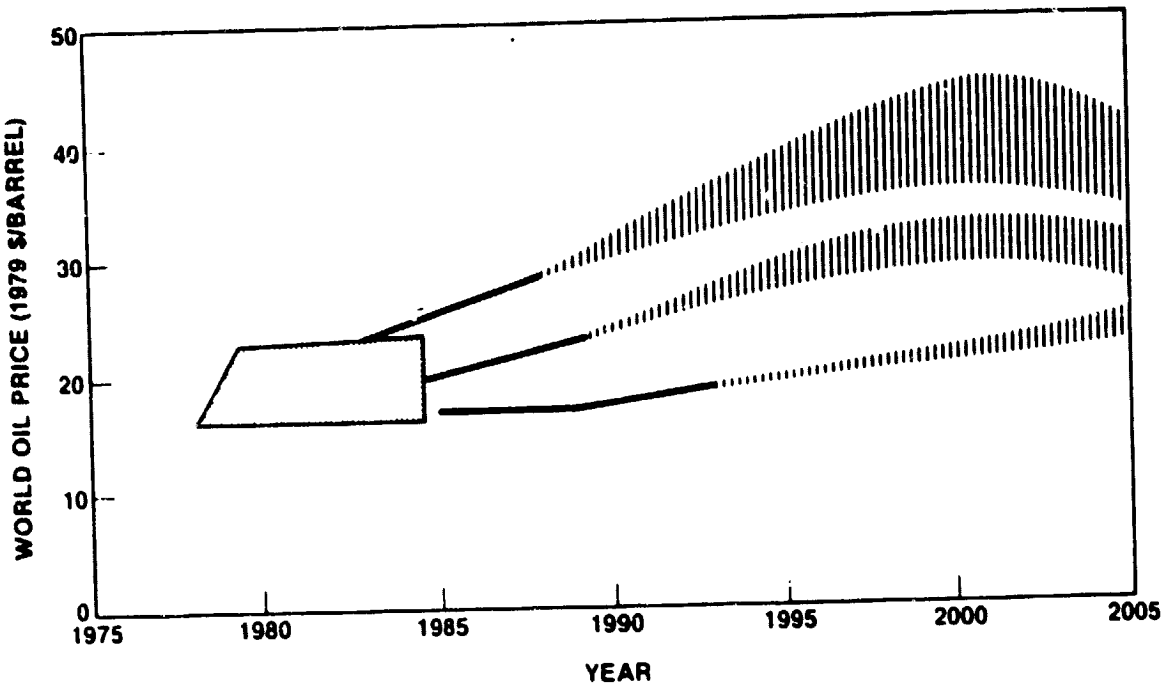
STEA - STATEMENT OF PURPOSE
(as outlined in the proposed By-Laws)

- TO PROVIDE INDUSTRY AND UTILITY INPUT IN NATIONAL, STATE AND LOCAL GOVERNMENT PLANS AND PROGRAMS AFFECTING SOLAR THERMAL DEVELOPMENT AND TO PROVIDE INFORMATION CONCERNING INSTITUTIONAL BARRIERS AND ECONOMIC INCENTIVES RELEVANT TO SOLAR THERMAL DEVELOPMENT AND IMPLEMENTATION
- TO ENLIST THE PARTICIPATION, SUPPORT AND VIEWPOINTS OF EDUCATIONAL, CONSUMER AND ENVIRONMENTAL GROUPS ON MATTERS CONCERNING SOLAR THERMAL POWER DEVELOPMENT
- TO FAMILIARIZE AND EDUCATE THE PUBLIC AS TO THE BENEFITS OF SOLAR THERMAL POWER AND PROMOTE ITS USE IN THE PUBLIC SECTOR THROUGH TECHNOLOGY TRANSFER METHODS AND PROMOTIONAL ACTIVITIES
- TO ASSIST AND FOSTER INDUSTRY AND UTILITY PARTICIPATION IN THE SOLAR THERMAL FIELD THROUGH INFORMATION TRANSFER AND OTHER SERVICES
- TO FUNCTION AS A FORUM FOR INFORMATION AND TECHNICAL TRANSFER, DISCUSSION AND RESOLUTION OF ISSUES AND PROBLEMS AFFECTING THE SOLAR THERMAL INDUSTRY, AND TO PRESENT A UNIFIED VOICE TO GOVERNMENT WHICH ARTICULATES THE VIEWPOINT OF THE SOLAR THERMAL INDUSTRY
- TO FOSTER AND DEVELOP INTERNATIONAL MARKETS FOR SOLAR THERMAL TECHNOLOGIES
- TO ACCELERATE THE DEVELOPMENT OF SOLAR THERMAL TECHNOLOGY INTO AN EFFICIENT AND COST-COMPETITIVE ENERGY ALTERNATIVE

09059-3

THREE PATHS FOR WORLD OIL PRICES

(1979 DOLLARS PER BARREL)



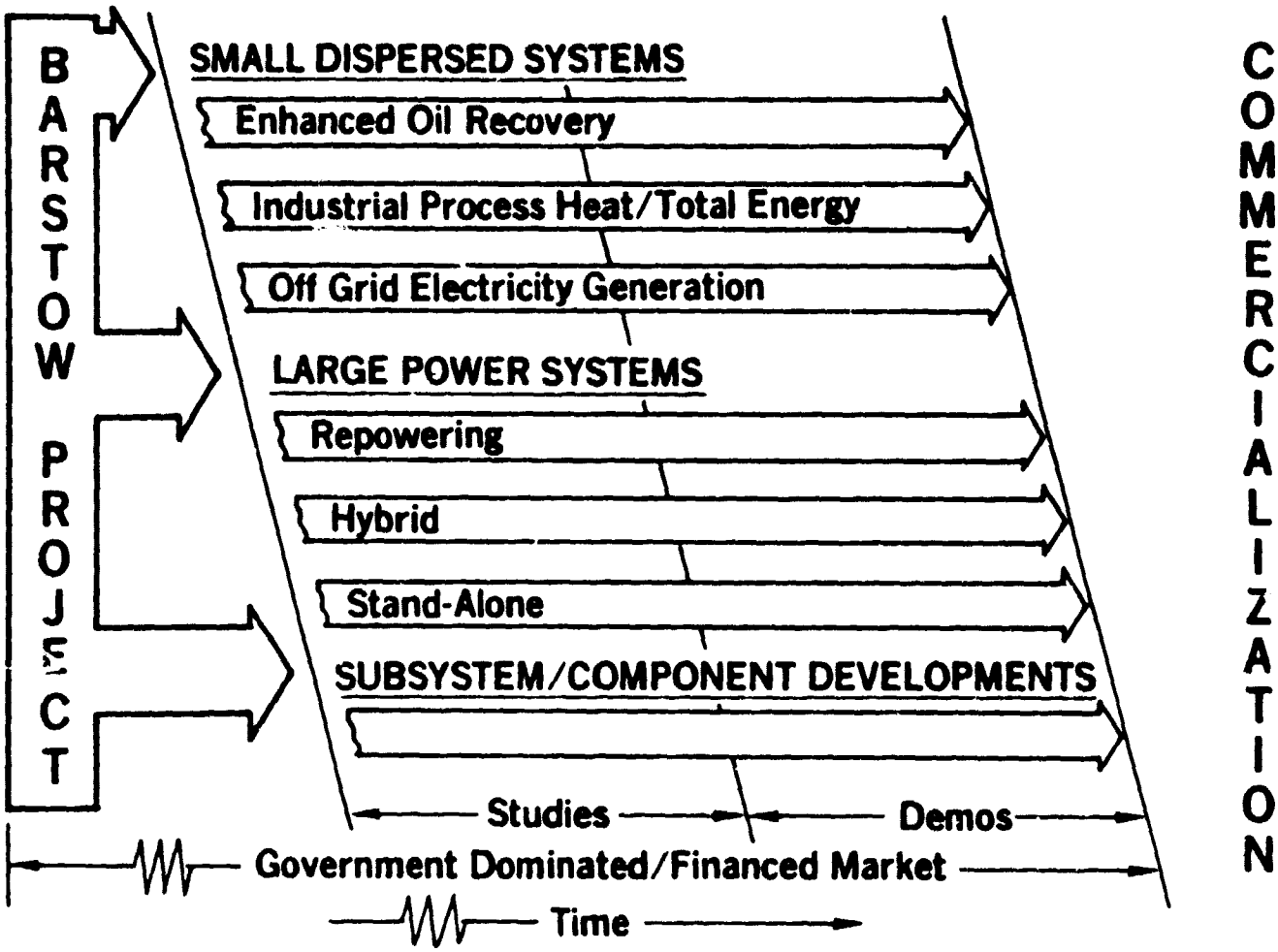
ATTRACTIVE FEATURES OF SOLAR THERMAL ELECTRIC FOR US INDUSTRY

- TECHNICAL READINESS
- MULTI FUEL - SOLAR, WOOD, PEAT, ETC.
- MULTI APPLICATION
- SCALABLE IN SIZE
- TECHNOLOGY OFFERS "PRODUCT LINE" LEVERAGE INTO OTHER AREAS
- LARGE FUTURE MARKET
- MARKET ACCESS DISTORTED BY GOVERNMENT SUPPORT OF OTHER TECHNOLOGIES

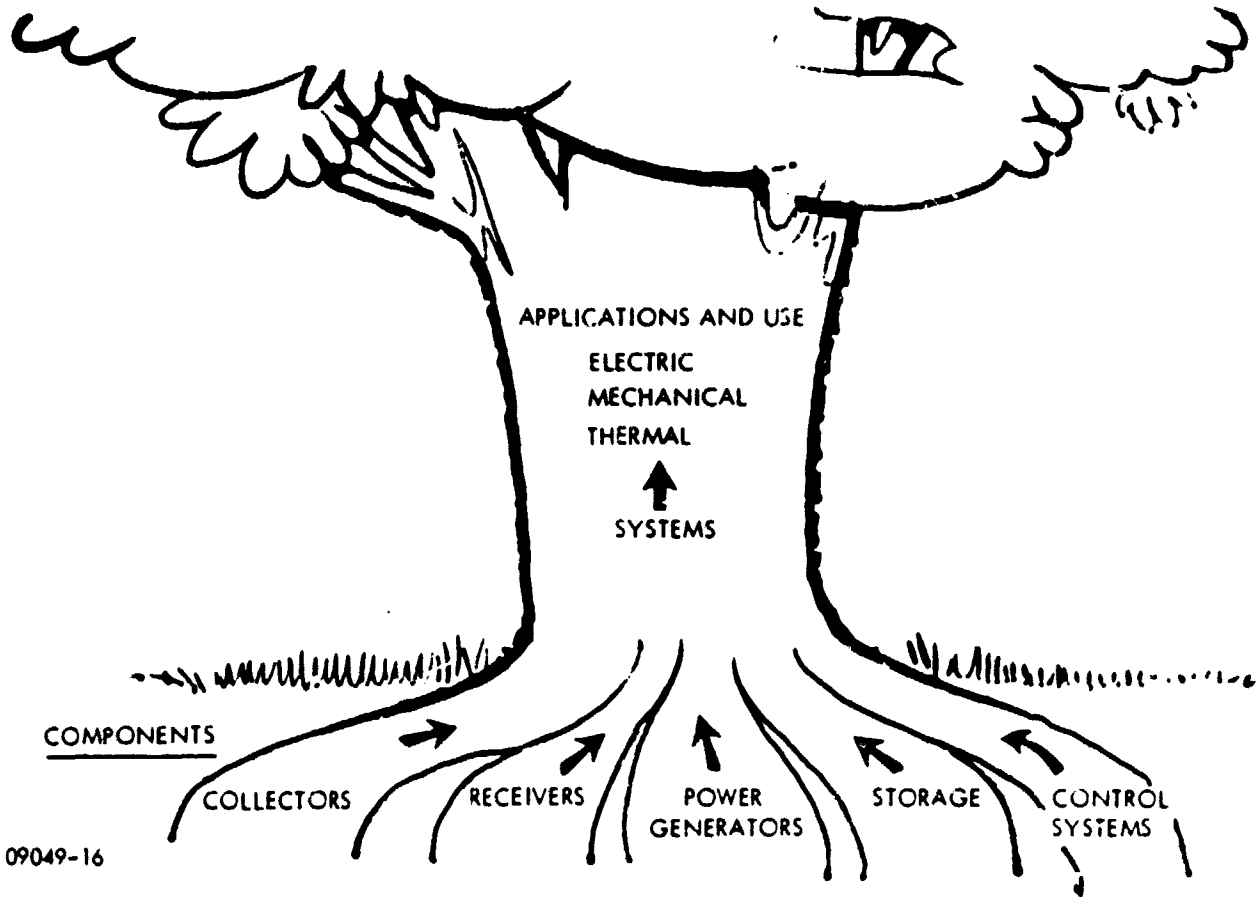
REQUIREMENTS FOR COMMERCIAL SOLAR INDUSTRY

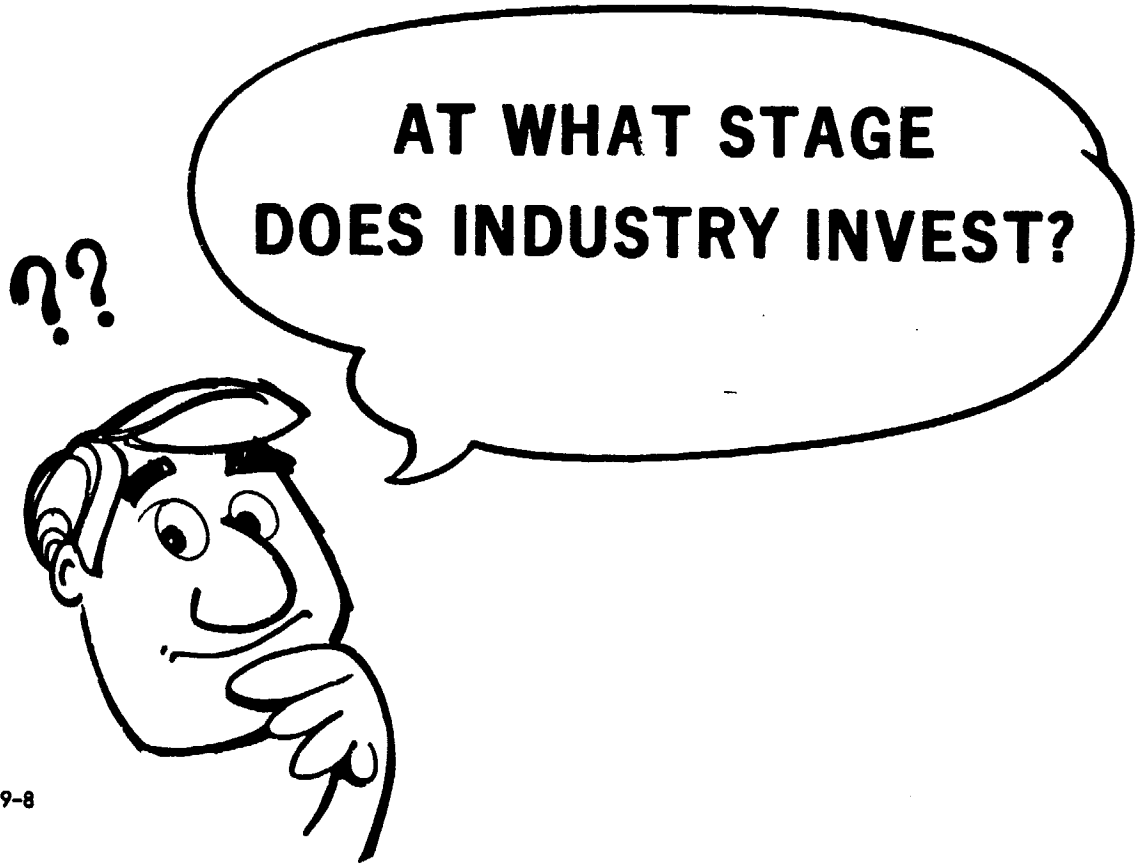
- TECHNICAL READINESS
- SIGNIFICANT MARKET (MULTIPLE APPLICATIONS)
- COMPETITIVE SOLAR PRODUCT
  - NEAR TERM: EXPENSIVE FUELS – FAVORABLE LOCATIONS
    - OIL, REFINED AND DISTRIBUTED
    - SYNTHETICS FROM COAL
  - FUTURE: ALL FUELS
- JOINT PARTICIPATION OF GOVERNMENT, INDUSTRY AND USERS

SOLAR THERMAL MARKET DEVELOPMENT



THE MARKET PRODUCTS AND SYSTEMS





09059-8

INDUSTRY STRATEGY FOR GROWTH BUSINESS

METHODOLOGY

- RETURN ON INVESTMENT
- COMPETITIVE POSITION (MARKET SHARE)
- INDUSTRY CONDITION

MANY WAYS TO PRESENT STRATEGIES (MORE PROMINENT)

- BOSTON CONSULTING GROUP
- McKINSEY/GE
- ARTHUR D. LITTLE

ETC.

NINE PARAMETERS FOR ROI PRODUCT PLANNING

- INVESTMENT INTENSITY
- PRODUCTIVITY
- MARKET POSITION
- MARKET GROWTH
- PRODUCT QUALITY AND SERVICE
- INNOVATION
- VERTICAL INTEGRATION
- COST PUSH
- STRATEGIC EFFORT CHANGE

RESULTS OF ANALYSIS OVER 1,000 COMPANIES

- MARKET SHARE IS LARGEST FACTOR ON PROFITABILITY
- TECHNICAL INNOVATION WITHOUT MARKET SHARE HAS LITTLE IMPACT ON PROFITABILITY
- MARKET SHARE IS EXPENSIVE TO PURCHASE

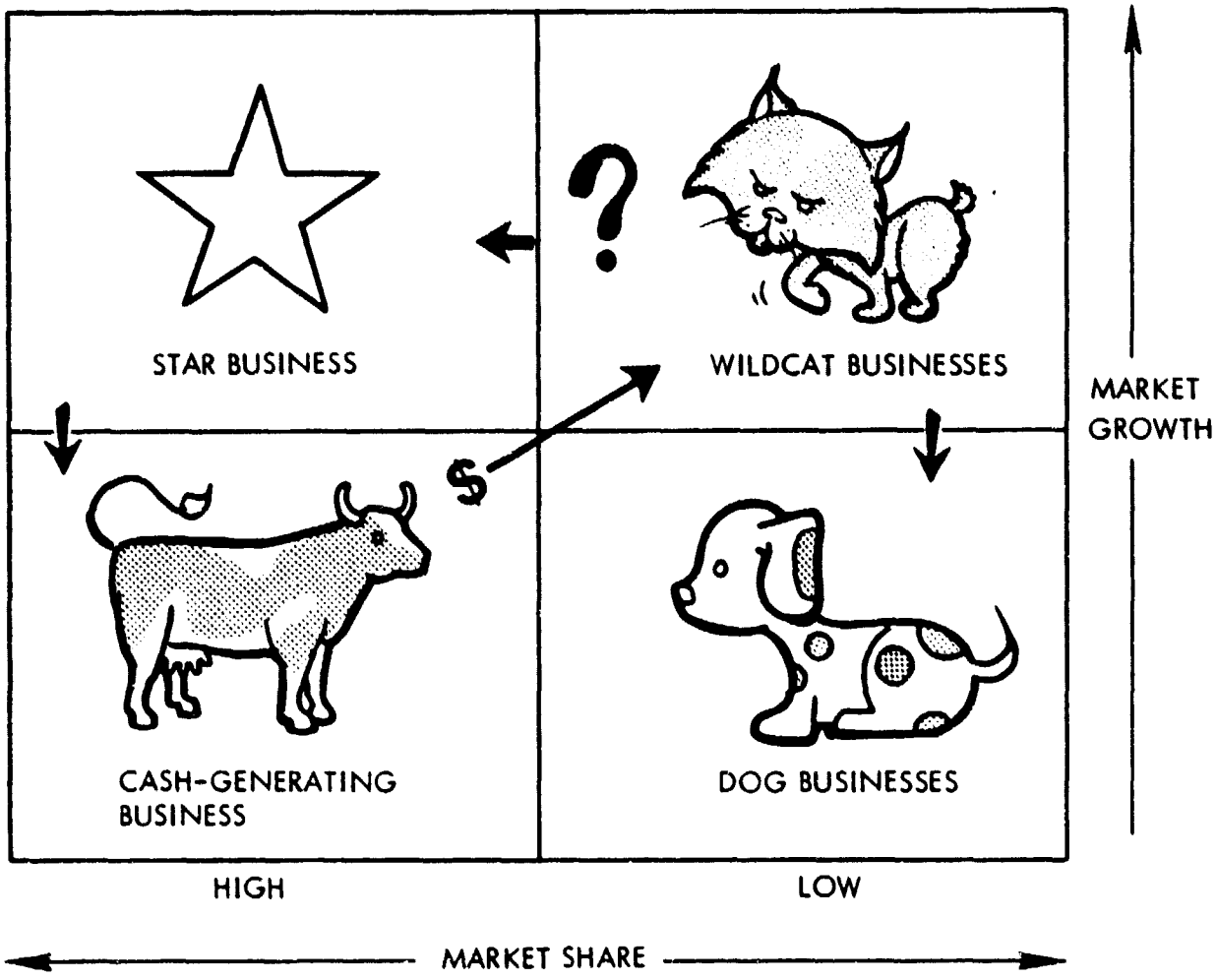
COMPETITORS

FOREIGN MARKET SHARE IS BEING

CAPTURED BY LESS THAN OPTIMUM PRODUCTS

FRENCH, GERMAN, JAPANESE COMPANIES

WITH THEIR GOVERNMENT SUPPORT


STAR BUSINESS
WILDCAT BUSINESSES
CASH-GENERATING BUSINESS
DOG BUSINESSES
$
MARKET GROWTH
HIGH
LOW
MARKET SHARE

STRATEGY

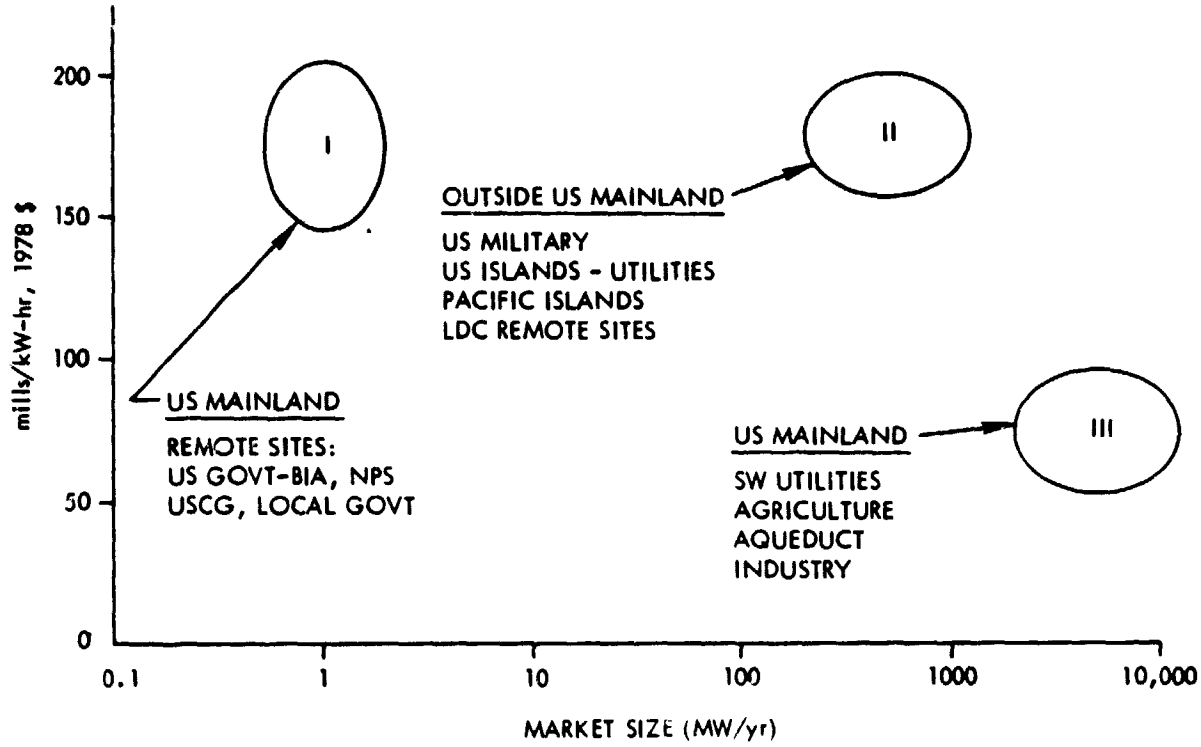
SITUATION

STARS	-	MAINTAIN OR INCREASE MARKET DOMINANCE
COWS	-	LITTLE INVESTMENT, PROFITS HIGH BECAUSE OF DOMINANCE
WILDCATS	-	REQUIRE HIGH INVESTMENT, QUESTIONS NOT ALL BECOME STARS - THE CHIEF SOURCE OF DOGS
DOGS	-	"BOW WOW" - LITTLE FUTURE

SMALL SOLAR THERMAL ELECTRIC

- NO STARS
- NO COWS
- SOME DOGS - SOME RELEGATED PREMATURELY
- PLENTY OF WILDCATS

POTENTIAL MARKET SIZE AND ENERGY COST GOALS 1990 - 2000



09049-14

THE INDUSTRY IS CHARACTERIZED BY LOTS OF

'COMPONENT MANUFACTURERS'

RECUPERATORS, ENGINES, DISHES

FEW SYSTEMS

STAGES OF PRODUCT GROWTH

R&D	R&D MODEL	PREPROD	SERVICE TEST MODEL	PRODUCTION	PRODUCT IMPROVEMENT
TECHNICAL ISSUES	DEMONSTRATE THAT IT WORKS	DESIGN TO COST	MAINTAIN-ABILITY	ECONOMIES ON SCALE	COMPETI-TION
SCIENCE	TEST THEORY	"SPEC" FOR MARKET SHARE ROI	RELIABILITY	PRODUCTION SCHEDULES	CUSTOMER INTERFACE
DEFINE OPTIMUM	TEST BOUNDARY	PRODUCIBILITY	PERFORMANCE OVERTIME		SERVICE
BOUNDS ON PERFORMANCE	VALIDATE COMPONENT PERFORMANCE	TOOLING			IMPROVE PERFOR-MANCE
IDENTIFY COMPONENTS		CAPITAL EQUIPMENT			

ROI
COMPETITION
WARRANT
SERVICE

WHAT DOES IT PROFIT

US

TO CAPTURE EVERY BTU

AND

LOSE $/KILOWATT

TO

OTHER ALTERNATIVE ENERGY

SOURCES

PRECISION OF A COMPONENT

IMPACTS THE

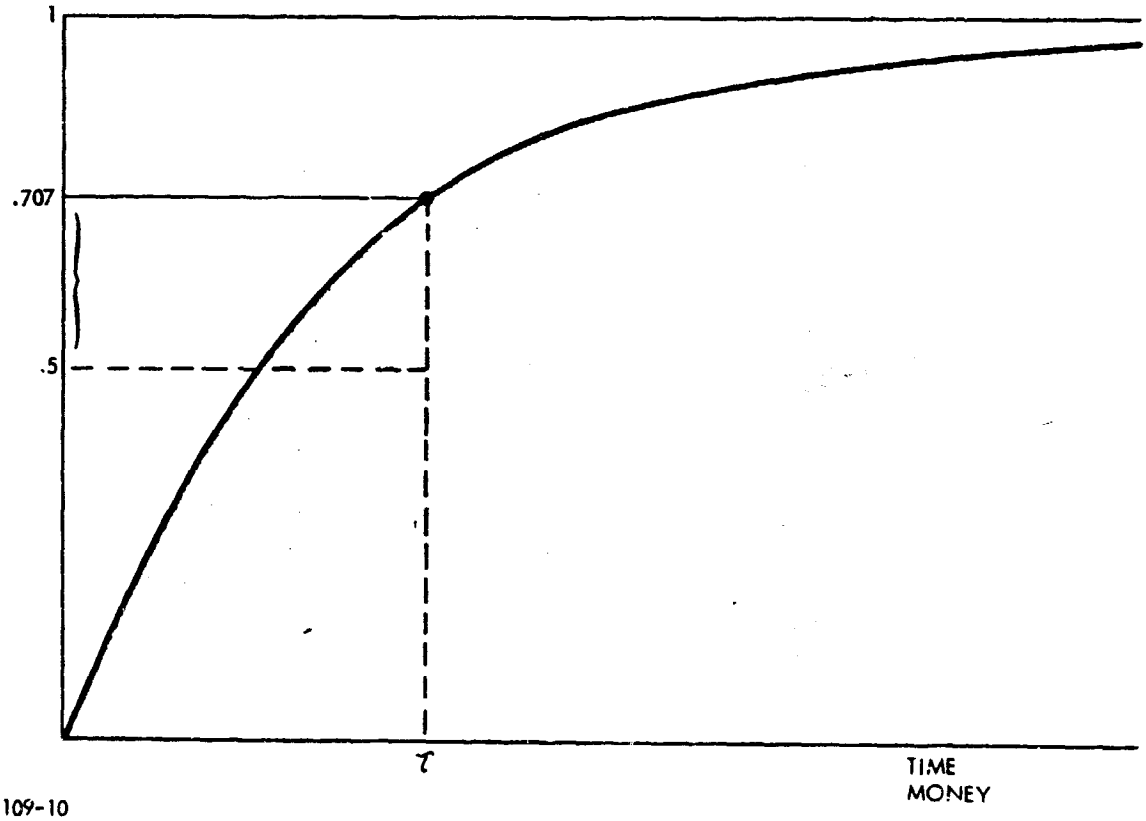
ECONOMY OF

PRODUCTION SCALE

THAT CAN BE

ACHIEVED

TECHNOLOGICAL PRODUCT PERFORMANCE CAPABILITY



09109-10

THE CLOSER TO

"TECHNICAL OPTIMUM"

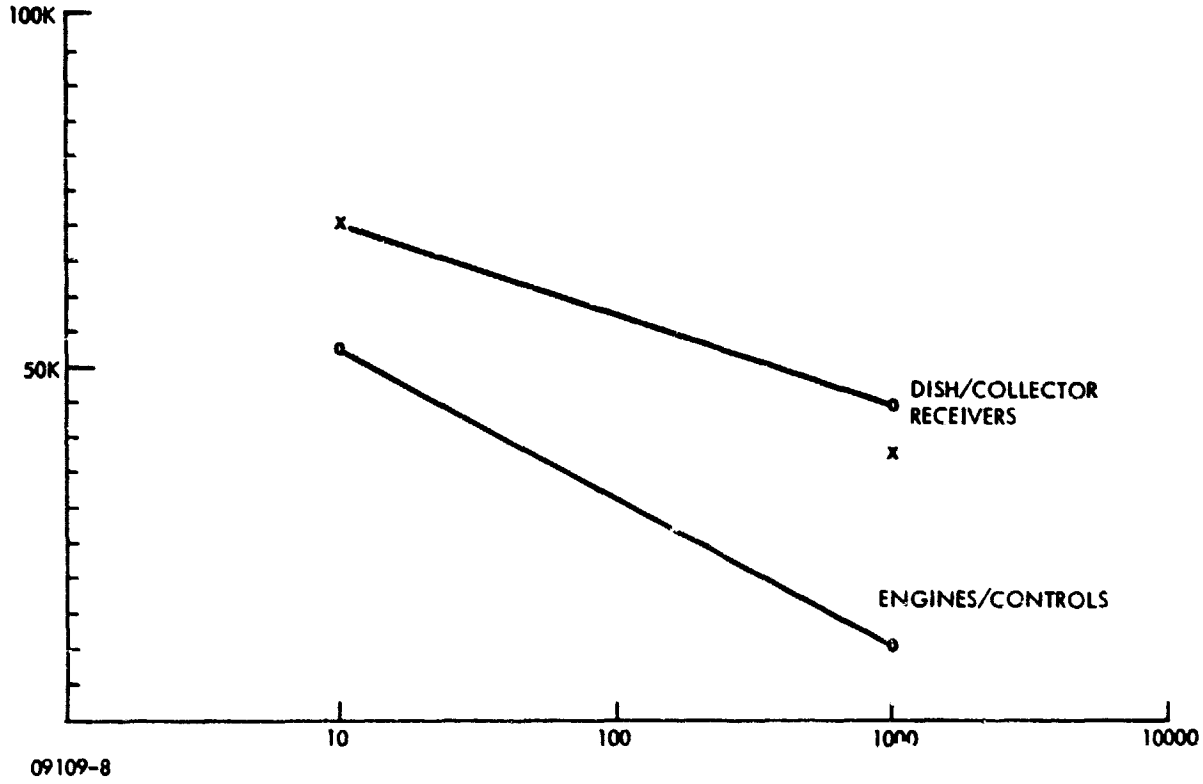
THE GREATER SERVICE AND MAINTENANCE

THE LESS RELIABLE

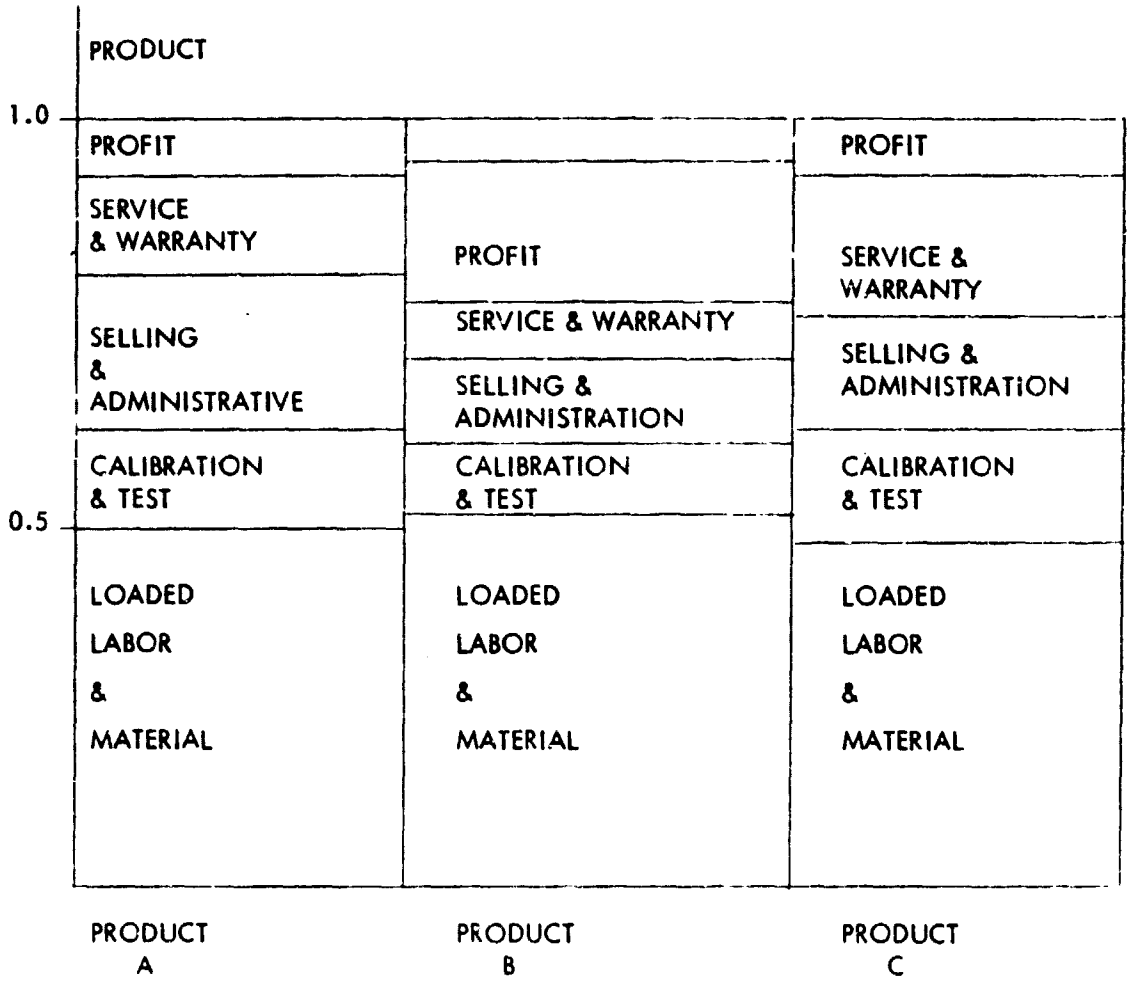
THE GREATER INVESTMENT

THE LESS LIKELIHOOD OF FIELDING A PRODUCT

COST AND PRODUCTION ESTIMATES SOLAR THERMAL COMPONENTS



ELEMENTS OF PRODUCT MARKET PRICE



09119-4

DESPITE TECHNICAL READINESS

PRODUCT

SERVICE AND WARRANTY POLICY AND COST

ARE STILL

?

FOR SMALL SOLAR/THERMAL SYSTEM

SERVICE TEST MODEL PROGRAM

OPERATION UNDER SUPERVISION

- SPECIFICATION FOR APPLICATION NOT OPTIMUM
- TESTS DONE AT SITE NOT LABORATORIES
- OPERATION FOR HUNDREDS OF HOURS

  MAINTENANCE - AT INTERVAL, MO, PROCEDURE

  PERFORMANCE -

  RELIABILITY -

- REPORT BASELINE FOR

  PRODUCT INTRODUCTION

  PRODUCT IMPROVEMENT PLAN

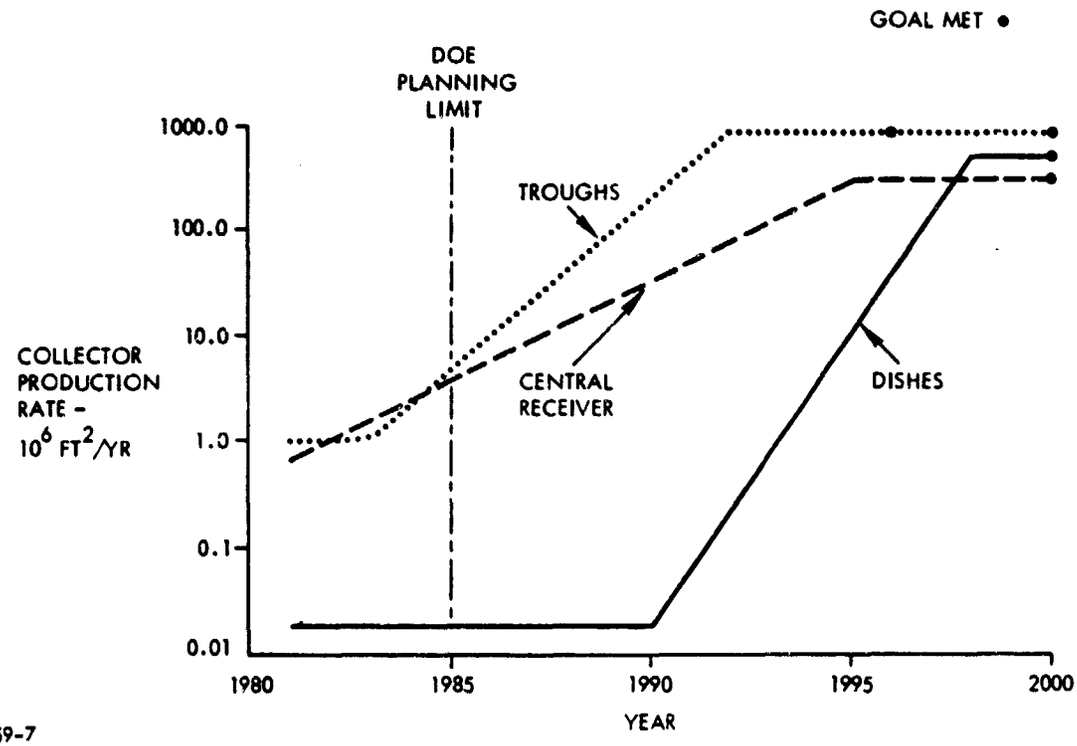
  PRODUCT R&D PLAN

SERVICE TESTS MODEL

OBJECTIVES: PROVIDE DATA FOR ESTABLISHING PRODUCT WARRANTY

- ESTABLISH "PSUEDO DOMESTIC" MARKET TO UNLOCK CORPORATE PRODUCT INVESTMENT
- PROVIDE MARKET PENETRATION FOR U.S. INDUSTRY IN FACING CHALLENGE OF FOREIGN COMPETITION
- PROVIDE REALISTIC DATA ON AVAILABLE ECONOMIES OF SCALE

MINIMUM PRODUCTION RATE VERSUS TIME TO MEET 3 QUAD GOAL

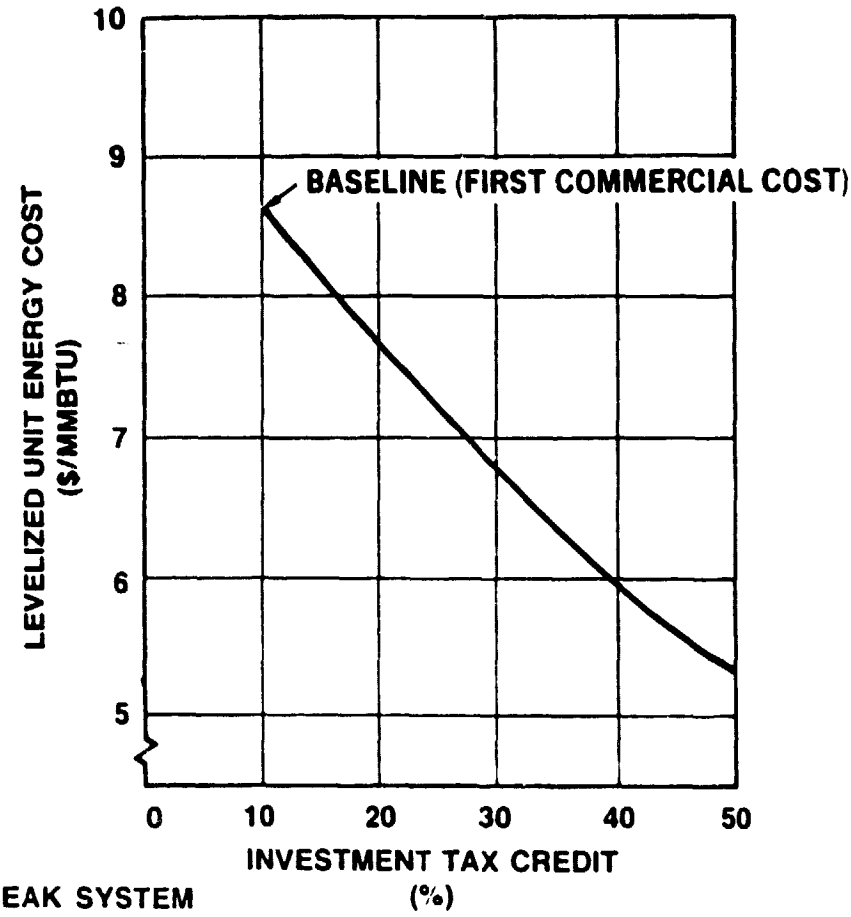


09059-7

FUNCTION OF GOVERNMENT

- DEFINE APPLICATIONS
- SET A GOAL FOR BTUs
- COMMITMENT FOR FIVE YEARS OF USE
- PROVIDE DATA ON
  - PERFORMANCE
  - MAINTAINABILITY
  - RELIABILITY
- "BE THE COW"

IMPACT OF INVESTMENT TAX CREDITS ON SOLAR COSTS*



*125 MMBTU/HR PEAK SYSTEM

CREATING A MARKET FOR SOLAR THERMAL # IN ADDITION TO R&D BASELINE

	1981	1982	1983	1984	1985
DOE					
DOD ARMY NAVY AIRFORCE					
DEPT OF STATE AID					
DEPT OF AGRICULTURE					
STUFA					
HUD					
DEPT OF COMMERCE					
SIZE - A > 1 MW 100 KW B < 1 MW 50 KW C 100 KWe 10 KW D 50 KWe	POWER TYPE RANKINE STERLING BRAYTON	COLLECTOR TYPE TROUGH DISH FIELD	APPLICATION THERMAL (IPH) MECHANICAL ELECTRICAL		

SEIA/STEA POSITION

- STATUTORY COMMITMENT TO DPR 3 QUAD GOAL
- CONTINUED R&D
- AGGRESSIVE PROGRAM OF STM'S AND DEMONSTRATION - CREATES "MARKET NOW"

  APPLICATION ORIENTED

  GOVERNMENT AGENCY - USER
- TAX CREDIT FOR INDUSTRIAL USE

The following question was directed to and answered by Mr. John Connolly, SEIA:

Q. "How important do you consider the near term foreign market for solar thermal technology?"

A. "The existence of a foreign market for solar thermal is very real. The economic requirements exist everywhere today, yet one problem has been that the customer has no money. Another problem is that perspective customers are skeptical because the U.S. is not using the technology."

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"THE ROLE OF CONGRESS"

Senator Pete V. Domenici (R-NM)

Good morning! When I accepted your invitation to speak at your solar workshop, I had no idea I would be getting up with the sun to be here.

As I understand it, you have been spending several days talking about solar thermal electric technologies from the standpoint of what the users of these technologies need and what the producers have to offer. The users, in this case, are different groups within the Federal Government; and as such, I would like to speak with you about the role of Congress in promoting and encouraging this "market" activity. After all, who holds the purse strings?

Generally speaking, you could characterize solar power as the apple pie issue of the Congress' eye. There are very few Congressmen who would vote against a piece of solar legislation on the floor of the House or Senate where they are truly under the scrutiny of their constituencies. This would lead you to believe that any solar bill introduced in the Congress was bound to pass. Why, you might expect the Washington Monument to be covered with solar cells if it were not for the crucial role that Congressional Committees play in molding such legislation. Committees such as the Senate Energy Committee, the House Commerce Committee, and the House Science and Technology Committee have the job of doing the substantive work and real analyses that go into good solar legislation.

A question that frequently comes to my mind in the hearings we hold in the Energy Committee is: Why do we need this legislation? That may sound like an obvious question with an equally obvious answer; but, in making public policy decisions on what incentives we are to provide for solar development, we have to craft the legislative remedy for the specific constraint to solar use. These constraints are many, and they are often not simply overcome.

They include:

Economic Constraints

1. High initial capital costs
2. Long payback on investment
3. Risk of consumer indifference

Institutional Constraints

1. Lending institutions (FNMA and GNMA)
2. Prohibitive utility rate structures

Regulatory and Legal Constraints

1. No right to sunlight
2. Higher property taxes due to solar equipment resulting in longer payback

The incentives to overcome these constraints are many and, as I will describe, sometimes appear to have little to do with a specific constraint. I should also note that the Federal Government is not alone in its desires to promote solar use. Since 1974, 22 states have passed laws exempting solar equipment from sales taxes. Another 27 states have lowered the property taxes on solar equipment. Several states like my own, New Mexico, support solar R&D and encourage the development of solar industries.

At the Federal level, a number of steps have been taken to assure the consuming public that this developing industry is an honest one. Legislation calling for performance standards and certification procedures has been passed and a number of direct economic incentives were included in The National Energy Act such as:

1. An income tax credit for solar equipment
2. Likewise, a business tax credit
3. Loan support for heating and cooling equipment
4. $100 million for solar devices in fed[illegible] buildings
5. $98 million for federal purchase [illegible]taic cells

These last two provisions of The Nationa[illegible] Act may seem somewhat unusual if our goal was to promote the use of solar in the private sector, but they were designed to do just that.

Not only was the tool of federal procurement used to foster widespread demonstration of the utility of these different solar technologies, but these programs were a way to promote the industries. In the instance of the photovoltaic procurement, the goal was to promote the industry and, therefore, lower the cost of the technology by bringing the industry along its "learning curve." This program's intent may appear to be obvious to you and most virtuous at the same time. Remember though that similar approaches had never been pursued to benefit the civilian population. The Defense Procurement Act was designed to promote certain industries vital to the National Defense, not industries vital to the consuming citizen.

The idea of federal procurement of solar technologies goes to the heart of what you must have been discussing over the past few days. I am sure for the industry representatives the question of whether this "tool" will be used in the future must be an important one.

In this regard, I must discuss with you some of the different philosophies I see expressed on the Energy Committee as we work on solar legislation.

There are those Senators who believe that the marketplace should be allowed to work and the Federal Government has no role in the promotion of the solar industry. Those Senators are a small minority; and, as time goes on, they would appear to be growing smaller as we gradually realize that the development of alternative energy sources is in the national interest.

Other Senators believe R&D is as far as we should go in the promotion of solar energy by the Federal Government. Obviously, support of this new industry by cost effective federal procurement goes beyond this and even beyond simple demonstration programs. The key to the acceptance of this strategy has been that the procurement is on a "cost effective basis." Because of this, and the realization by many Congressmen that solar technologies have wide applications even under this constraint. I believe you will find further encouragement of federal procurement in the solar area.

The following questions were directed to and answered by Senator Peter Domenici, (R-NM):

Comment

"One problem that has been seen in the DOD market is that Senator Hart's legislation allowed for a life cycle cost benefit that was really definable. This is not solar's position. In order to come close to having a life cycle break even point, a lot of hand waving has to be done. New legislation should allow for some latitude."

Response

"If experts can make it clear that the latitude can produce positive potential for getting away from this barrier, I am supportive of that latitude. If this cannot be displayed to the committees, there will indeed be difficulties."

Q. "There is a very interesting relationship between the synthetic fuels program and this technology. Congress is planning to spend 30 to 40 billion dollars in synthetic fuel development in order to save 2 million barrels of oil which we could simply stop using by other measures. Why, if Congress is willing to spend that amount of money in synthetic fuels, will they not spend the same kind of money for solar development? There is a lot more potential for solar."

A. "As a supporter of synthetic fuel spending, perhaps I can respond acceptably. I see the spending as an investment rather than as a use of tax dollars. For example, I am convinced that if we move ahead with flexible authority to guarantee loans, to set prices one is willing to pay, and to guarantee purchases in three or four synthetic technologies, that we will not pay one cent of tax dollars when these things come on board. If prices are set now, by the time plants are up, oil will be so expensive that synthetics will be commercial and

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the guarantee will not be used. I see no way for the U.S. to remove itself from dependence on huge quantities of crude oil from now to around the year 2010 or 2020. Nor are we going to be able to produce sufficient quantities of crude. The deficiencies will be met by importing, or by production of synthetic fuels. America can progress in conservation and in alternate energy, but we must face a significant dependence on crude oil for a few generations to come."

Q. "In the course of this workshop a large number of good, potential applications for solar thermal technology have been defined. Some of the problems associated with the technology are that it is still in development, and that it is so very flexible. In contrast to photovoltaics where actual units are physically functioning in well defined applications, solar thermal technology is still in flux and the spectrum of possible applications is wide. At this stage the final configuration is not one, but many. This makes it difficult for developers to present to implementors specific packages or goals. What practical steps can be taken by developers of solar thermal technology to advise and communicate to implementors the ideas and directions that appear practical?"

A. "Congress cannot explicitly concern itself with the technical aspects of development. The fact that the technology is so diverse makes it difficult for persons with less than broad authority to implement it. Hence, what must be done is to work with persons 'on the hill' who have legislative talents. Perhaps the best suggestion is to confront legislative draftsmen with your proposals, and work the procurement issue from there."

Q. "Do you feel that Congress is willing to pass fairly explicit solar tax shelter legislation; and is Congress able to engage in aggressive oversight of the implementation of programs which they pass in conjunction with DOE?"

A. "Although I do not consider myself an expert in the field of taxes, I do think a willingness exists in Congress to consider such legislation. Perhaps the more closely related to financial matters, such as someone in Ways and Means, should be contacted. Unquestionably, DOE is doing a poor job of overseeing programs, and Congress is doing a worse job in watching DOE. Hopefully this can change."

Q. "Is there any current legislation concerning loan guarantees for utilities since they represent a large possible market?"

A. "No such legislation exists to the best of my knowledge. However, there is a lot of other legislation being passed around concerning solar. In addition to trying to pass a synthetic fuel package within the next year (governmental promotion), Congress will not likely pass a major solar bank proposal. This will be a source of Federally insured loans at a subsidized rate available to users of new solar technology. This should bring solar into more of a competitive posture."

WORKING GROUPS

WORKING GROUP I

PORTABLE POWER SYSTEMS

SUMMARY

As a result of the proceedings and discussions of Working Group I, the following summary was presented to the workshop.

A. Recommendations and Conclusions

(1) It is recommended that mobile solar power systems be defined as systems rated at 250KW or less.

(2) Solar applications appear limited in some tactical theater environments. Front-line and back-line represent the two possible areas of operations. Of these, back-line offers the only feasible applications: field hospitals, remote site communications, air defense artillery, and base camp operations.

(3) It is recommended that a study be done to concisely identify DOD's need for mobile solar systems. Perhaps this could be done by compilation of existing requirements documents.

B. Anticipated Useful Technology

(1) A standard family of multi-fueled heat engines should be developed.

(2) A modular "solarization kit" should accompany the heat engines. It would be comprised of a hybrid receiver, portable concentrator, standardized modular fittings (maintaining components), and a power regulating module.

C. Necessary Actions

(1) Constraints on the R&D budget should be relaxed.

(2) DOD market penetration must be accelerated.

(3) Incentives need to be provided for manufacturers.

(4) Joint DOD and DOE demonstration programs are possible and would facilitate action.

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- DEFINITION
  - MOBILE POWER SYSTEMS LESS THAN 250 KW_E

- SOLAR APPLICATIONS LIMITED
  - FIELD HOSPITALS
  - REMOTE SITE COMMUNICATIONS
  - AIR DEFENSE ARTILLARY
  - BASE CAMPS (TEMPORARY)

- STUDY REQUIRED
  - TO IDENTIFY DOD NEEDS FOR MOBILE SOLAR SYSTEMS

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- ANTICIPATED TECHNOLOGY
  - STANDARD FAMILY OF MULTI-FUEL HEAT ENGINES
  - SOLARIZATION KIT FOR ABOVE
    - A) HYBRID RECEIVER
    - B) PORTABLE CONCENTRATOR (I.E., FOLD-OUT)
    - C) MODULAR, STANDARDIZED BUILDING BLOCK COMPONENTS
  - POWER REGULATING PACKAGE

- REQUIRED GOVERNMENT ACTION
  - RELAX CONSTRAINTS ON DOD R&D (6.2 & 6.3A DEVELOPMENT OF ENERGY CONVERSION SYSTEMS)
  - INCREASE DOD R&D BUDGET
  - ACCELERATE DOD MARKET PENETRATION
  - PROVIDE TAX INCENTIVES FOR MANUFACTURES

- RECOMMENDATIONS
  - RELAX CONSTRAINTS ON DOD R&D (6.2 & 6.3A DEVELOPMENT OF ENERGY CONVERSION SYSTEMS)
  - INCREASE DOD R&D BUDGET
  - ACCELERATE DOD MARKET PENETRATION
  - PROVIDE INCENTIVES FOR MANUFACTURES
  - DEVELOP JOINT DOD/DOE ENGINE/GENERATOR DEMONSTRATION PROGRAM

WORKING GROUP I

PORTABLE POWER SYSTEMS

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2d LT Richard Honneywell	Air Force Aero-Propulsion Laboratory Wright-Patterson AFB	(513) 255-6235

WORKING GROUP II:
ISOLATED POWER SYSTEMS

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SUMMARY

The recommendations and observations of Group II are presented under two headings: Common Problems of Solar Technology, and Policy.

A. Common Problems of Solar Technology Development

(1) A twofold problem exists: the problems created or solvable by governmental action, and the high capital cost of solar development.

(2) A marketing or manufacturing problem exists in the premature choice and support of one technology vs. another.

(3) The slow, unaggressive deployment of experiments hinders progress.

B. Policy

(1) It is suggested that DOE catalyze the entire process of commercializing a technology by:

(a) Accelerating experiments to increase technical knowledge.

(b) Providing high visibility.

(c) Recommending legislative incentives such as cost sharing and subsidized loans.

C-5

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Questions Examined:

1. What are the subcategories of isolated power applications?

   Communication systems
   Radio beacons
   Pipeline pumping
   Remote village and communications
   Satellite tracking
   Fire stations
   Railroad crossings
   Navigation aids
   Microwave repeater sites
   Irrigation
   Aqueducts
   Highway protection

2. What are the major needs for isolated power? Are there differences in military and civil applications?

   Military Requirements
   - Lack of detectability and low signature.
   - Mobility is a military requirement only.
   - Fungus/salt spray, temperature extremes.
   - Cost, tax incentives and payback issues are civil requirements only.

3. Are there essential differences in civil and military requirements for isolated power systems which imply differences in plant requirements for a system to meet similar needs?

   See discussion summary.

4. Cost projections indicate that a solar hybrid system which replaces 20-80 percent of standard fuel consumption, depending on duty cycle

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and climate, is the most feasible system from a cost and operational standpoint. It is more difficult to get a handle on the impact of the reduction of transportation and storage after the point of purchase. For civil and military applications, how valuable would such a reduction be?

Not addressed

5. Is the high initial cost of solar a barrier to use of solar thermal power systems for civil and military isolated applications? If so, what could be done to lower this barrier?

   Yes, but life cycle cost are also critical.

6. Are there particular applications for power systems which are especially good candidates for DOE/DOE or DOE/private sector, cost sharing engineering experiments to demonstrate technical feasibility for solar thermal electric power systems?

   Most government agencies and private sector concerns are not in solar thermal business and will not cost share above cost of a conventional system.

7. Would a demonstration of system cost and operational effectiveness in a military application be considered adequate to evoke positive purchase decisions in the private sector? Would any particular application be preferable?

   Probably not--see discussion summary.

8. What action would be necessary to elicit a decision by corporate manufacturers to invest in production of a solar thermal electric power system for remote applications?

DOE should announce that one to five installations per month will be made for the next five years. Typical applications would be post offices, federal buildings, etc. DOE would decide on the type of system to be installed in each, i.e., point focus Rankine, point focus Brayton, point focus Stirling, line focus Rankine, etc. Contract award would go to a low bidder. Manufacturers would retain rights and data and would know that there would be a continuing market for pilot production.

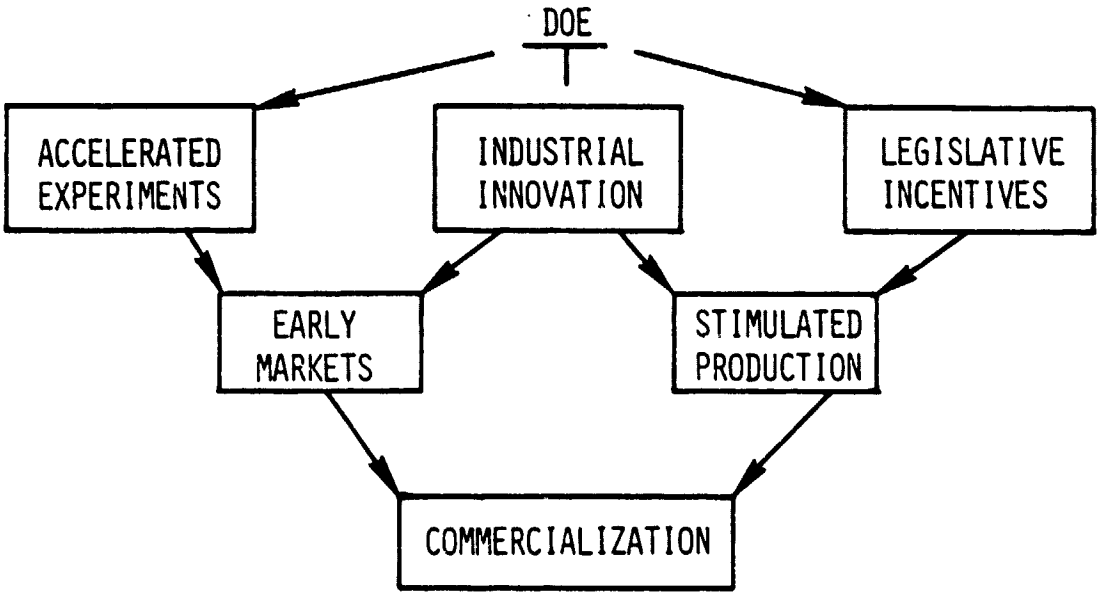
There exists substantial confusion regarding the role of U.S. government programs in the development of solar thermal power. The attendees perceived a desire on the part of some factions of DOE to make technical choices (photovoltaics vs. solar thermal, central power vs. distributed generation, etc.) between technologies. Such choices are unwise for two reasons. First, it is too early in development to make such choices--hard experimental results are not yet available. Second, it is not a government function to make such choices. These are made best in the marketplace. The proper function of government programs is to develop technical options and stimulate those technologies offering promise for the future. At this point, DOE has the luxury of being able to develop multiple technical options. That luxury should be exploited and used to maximum advantage in developing a range of options to meet the nation's energy needs.

The chief impediment to accelerated experiment deployment is the high cost of capital equipment. An accelerated schedule for experiment deployment is urgently needed, especially for isolated load experiments. Legislative incentives, tax credits, accelerated depreciation etc., are more suitable incentives as production capabilities improve and the technology matures.

Once the experiments have been completed and the results analyzed, users will be able to select the most appropriate system from a variety of choices. In this regard, military demonstrations, by themselves, are not sufficient.

No hardware, regardless of the attractiveness of an incentives program, however, will be successful unless a cost effective application is available. The deployment programs must be very careful, therefore, to proceed with a full understanding of the market and its structure.

POLICY



ISOLATED POWER SYSTEMS

- DECREASED VULNERABILITY (FEWER FUEL LOGISTIC PROBLEMS)
- LOWER LIFE CYCLE COSTS (INCREASED CAPABILITY)

- PROBLEMS
  - U.S. GOVERNMENT (DOE) STRATEGY
    - A) PREMATURE CHOICES
    - B) SLOW EXPERIMENT DEPLOYMENT
  - COSTS
    - A) HIGH CAPITAL COST
    - B) UNCERTAIN LIFE CYCLE COST

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WORKING GROUP III

FACILITIES POWER APPLICATIONS

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SUMMARY

The following summary represents the opinions and conclusions of Group III as presented to the workshop.

A. Considerations of Institutional Barriers

(1) In order to allow military clockwork to begin phasing in and using new technologies, development cycles must be considered. Plans for rapid identification of technologies and fundings are needed to implement this procedure.

(2) The establishment of military training, personnel programs, and maintenance procedures must be considered.

(3) An O&M data base is necessary which requires a testing period and implementation.

(4) A military reluctance to develop in-the-field solar systems exists.

(5) On-site construction may cost as much as 2 to 3 times as much as factory construction.

(6) Due to plant designs and land availability, the tradeoffs of centralized vs. distributed applications (thermal or electric) must be considered.

B. Energy Needs and Potential Problems

(1) Since tactical military applications require extensive survivability developments, facilities applications represent the best opportunities.

(2) A potential problem exists with public skepticism of cost and technical data that is displayed by military projects.

(3) Progress should not be hindered by holding original designs to stringent performance requirements.

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C. Requirements

(1) Especially deserving of development are the versatility, modularity, hybridization, and co-generation aspects of the technology.

(2) Tradeoffs between large utility or private electric generating systems must be considered.

(3) Multi-year programs with user needs vs. actual product capability should be incorporated.

Summary and Recommendations

Group III discussions concerning facilities applications evolved into two distinct areas that reflected the intent of the workshop, i.e., military and civil. Civil applications discussed were almost entirely industrial as opposed to other commercial-type or residential applications such as housing developments, hospitals, supermarkets, etc. The discussion of military applications did encompass these other applications from the point of view that they are "duplicated" on a military installation.

The group reached a strong consensus in formulating two major recommendations: (1) that solar thermal electric technologies need an FPUP-type program, and (2) the Department of Energy must develop a long-range plan for commercialization of PFDR systems.

A FPUP-type program is needed to establish a strong commitment by the government to pursue solar thermal electric systems. This emphasis, as shown by infusion of substantial dollars ($100 million), will provide a clear incentive to system manufacturers to begin planning for production capacities that can support the market growth required to meet stated federal alternative energy goals. A second essential characteristic of an FPUP-type program for military applications is that the "blanket check" aspect allows the services to purchase hardware without going through normal procurement policies and channels. This point addresses a strong area of concern for military applications. Military representatives believe that present institutional barriers must be relaxed if solar thermal electric systems are to be purchased by the services. Conflicting legislation, military regulations, and OMB life-cycle costing procedures all work against the introduction into the military of alternate energy systems. The FPUP-type approach provides a convenient method of circumventing these "roadblocks" by allowing system hardware purchases under Research and Development funding.

The recommendation for a long-term alternate technology commercialization plan developed from recognition by the group membership that energy shortfalls are resulting in a growing awareness that alternate energy sources must be found. Pressures are being applied to both the military

and industry to reduce energy consumption and replace fossil-fuel derived energy with renewable forms. The origins for this pressure extend from federally mandated goals on the military side to notification by utilities of future inability to meet current electricity/fuel demands on the industrial side. Both groups are under management pressure to reduce escalating energy costs.

Group members believed that it is not clear which alternate technologies provide the most promise for accomplishing what is required to reduce these pressures. A federally approved plan that clearly identifies alternate energy technologies, funding levels, development phases and timetables, and decision points for system commercialization is necessary to provide input to long-term (5 to 7 years) investment and planning cycles.

Additional Military Applications Concerns

The group believes that the best military application is for base facilities as contrasted with remote sites or portable systems. The base facilities applications parallel civilian applications in that military bases can be considered as "small communities." If military applications are used for solar thermal electric system demonstrations, the group cautioned against the possibility of the general public not believing in a direct applicability to the civil sector. This results from the perceived tendency for the military to require stringent specifications and not be as demanding of a favorable cost/benefit ratio.

The military representatives expressed the opinion that personnel training and education programs are required to establish maintenance procedures and proficiency, and in a broader context, to promote overall awareness of solar thermal electric benefits. With regard to maintenance procedures, the military generally requires a substantial operations and maintenance data base to justify hardware specifications for system procurement. The magnitude of this data base usually requires data collection from 10 to 15 systems in operation for up to 5 years.

Another military concern expressed dealt with power interface requirements for specific applications. A suggestion was made that as a

given alternate energy technology develops, a cross-feed be established with user energy needs. In this manner, the energy system design and the user requirements can be optimized through a well-thought-out and timely interface definition.

Additional Civil Applications Concerns

As mentioned previously, civil applications centered almost exclusively on industrial applications. Group industry representatives believed that some form of government incentives were required to insure development of a strong solar thermal electric market; both for the technology systems manufacturers and the potential consumers. Conclusions were not reached as to the exact form for the incentives to take (depreciation allowance, short-term payback, return-on investment, cost sharing, etc.). The preferred form appears to be industry and accounting procedure specific.

A point was made that emphasis should be placed on factory construction for solar thermal electric systems. On-site construction costs can be a factor of two to four times higher than factory construction. Inherent in this recommendation is support for modularity since this would increase the utility of the product manufactured.

Group discussion addressed the area of centralized versus distributed systems. This issue is not only application specific (decentralized plants, land availability, etc.) but also dependent on the required energy form; e.g., electricity is relatively easy to distribute from a central generator but low- or medium-Btu process heat is not.

A final general observation was made by the industry representatives that industrial equipment is wearing out in many areas of this country. This could represent a "solar opportunity" as retrofit or replacement of current systems increases over the next 10 to 15 years.

General Solar Thermal Electric Discussion

The group believed that to meet specific military and civil energy needs the best attributes for solar thermal electric systems are system

versatility, external combustion heat engines, low temperature/high temperature operations, hybrid operations, and co-generation possibilities. The ability to provide both electricity and thermal energy is a definite plus as is the ability to provide incremental additions to satisfy the energy demand of a given application.

FACILITIES POWER SYSTEMS

A. ENERGY NEEDS/POTENTIAL PROBLEMS

- FACILITIES APPLICATION IS BEST MILITARY OPPORTUNITY FOR PFDR.
  - PARALLEL CIVILIAN APPLICATIONS
  - BASES ARE "SMALL CITIES"
- "MIL SPEC & DAMN THE COST" SYNDROME
- RELAXED PERFORMANCE REQUIREMENTS
  - COMPETE WITH "WALL PLUG"

B. HOW SOLAR THERMAL ELECTRIC CAN MEET THESE NEEDS

- VERSATILE: CAN UTILIZE RANKINE, BRAYTON, STIRLING. LOW TEMP/HIGH TEMP
- SUITABLE TO CO-GENERATION: CAN SATISFY THERMAL AND ELECTRICAL NEEDS
- SUITABLE TO HYBRID OPERATIONS
- SUITABLE TO OPERATION WITH STORAGE

C. SPECIFIC NEEDS BEST MET BY PFDR

- INCREMENTAL ADDITIONS TO CAPACITY, OR
- WHERE TWO TIER APPLICATION EXISTS
  - ELECTRIC POWER (HIGH QUALITY ENERGY)
  - THERMAL ENERGY (LOW-MEDIUM QUALITY)
- WHERE FIRM CAPACITY IS REQUIRED
- INDUSTRIAL USE OF ELECTRICITY
  - INCREASING OR DECREASING?

D. PROGRAMMATIC RECOMMENDATIONS

- MULTI-YEAR MILESTONE CHART
  - PERFORMANCE PROJECTIONS
  - COST PROJECTIONS
  - EARLY EXPERIMENTS
  - DEMONSTRATIONS

- TECHNOLOGY DEVELOPMENT AND POWER REQUIREMENTS OF USERS PROCEED IN PARALLEL TO IDENTIFY INTERFACE REQUIREMENTS EARLY.

INDUSTRIAL FACILITIES

- NEED GOVERNMENT INCENTIVES
  - DEPRECIATION
  - SHORT-TERM PAYBACK (ROI)
  - COST SHARING
- ENCOURAGE FACTORY CONSTRUCTION
  - MODULARITY
  - MINIMIZE ON-SITE CONSTRUCTION
- CENTRALIZED VS. DISTRIBUTED
  - DECENTRALIZED PLANTS
  - LAND AVAILABILITY
- INDUSTRIAL EQUIPMENT IN USA IS WEARING OUT
  - INERTIA
  - RETROFIT VS. NEW PURCHASE
  - SOLAR OPPORTUNITY?

MILITARY FACILITIES

- NEED FPUP-TYPE PROGRAM

- RELAX INSTITUTIONAL BARRIERS
  - CONFLICTING LEGISLATION
  - OMB COSTING PROCEDURES
  - MILITARY REGULATIONS

- DEVELOP 10-YEAR TECHNOLOGY COMMERCIALIZATION PLAN AT DOE
  - IDENTIFY TECHNOLOGIES/FUNDING LEVELS
  - ESTABLISH DECISION POINTS/DEVELOPMENT PHASES

MILITARY FACILITIES

- ESTABLISH PERSONNEL TRAINING/EDUCATION PROGRAMS
  - PROMOTE AWARENESS
  - DEVELOP MAINTENANCE PROCEDURES
  - ESTABLISH PROFICIENCY

- DEVELOP O&M DATA BASE
  - 10 TO 15 SYSTEMS IN THE FIELD
  - 5-YEAR OPERATION

- MILITARY RELUCTANCE TO INTRODUCE SOLAR
  - INERTIA
  - NO "TACTICAL SYSTEMS"
  - NO STRICTLY "BACK-UP"
  - NOT TRUE FOR FACILITIES APPLICATIONS

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WORKING GROUP IV

IMPLEMENTATION

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SUMMARY

Group IV presented the following opinions and suggestions to the workshop.

A. Topics of Discussion

(1) Rapid implementation of solar thermal technology is needed.

(2) Various barriers exist which prevent this rapid implementation.

(3) Military structures should not be changed for the purpose of implementing solar thermal technology.

(4) Implementation requires reliability, availability, maintainability and dependability.

(5) The hybrid features of solar thermal technology are most attractive to the military.

(6) Societal inertia that resists change also exists in DOD. The problem is apparent in both areas.

(7) Societal barriers may be overcome with tax incentives such as those existing in California.

(8) Government involvement in properly funded, well planned fast paced programs is essential to the rapid implementation of solar thermal technology. Private industry is not capable of doing it alone.

B. Specific Suggestions

(1) If new legislation is necessary, the political problem concerning passage of this legislation within Congress must be addressed. Industry probably shares this responsibility for supporting legislation and informing Congress concerning technical progress.

(2) On the non-legislative level, industry has public relations responsibility in conjunction with DOE.

(3) Position papers are needed.

(4) Industries must be prepared to exert political pressure

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(5) Procurement and patent barriers should be removed within DOE to allow for proper program designs.

(6) Procurement plans should be multi-year and comprehensive for technical development and commercialization.

(7) Goals must be determined.

C. Suggested New Legislation

(1) Small business needs the means and incentives for participation.

(2) State and local governments need involvement as well as the utilities.

(3) Legislation for oil displacement allowance is needed.

(4) Legislation is needed to involve DOD in the solar thermal program.

D. Possible Purchase Strategies

(1) Federal purchases in early years would aid technical development.

(2) Tax credits, mandatory service contracts, and government backed warranties would stimulate consumer use in the early stages.

(3) Government procurement could be accomplished through a savings paid procurement program.

In order to rapidly implement solar thermal technology within the Department of Defense, it is necessary to utilize the expedited DOD budget and procurement procedures. A supplemental program similar to the Federal Photovoltaic Utilization Program (FPUP) must be set up. A 10 to 12 year development time frame must be assured and in this way the procurement of solar thermal technology can occur in half the normal 20-year time limit. This would allow the DOD engineers and scientists to collect the operating and maintenance data on these systems necessary to establish their suitability to meet DOD requirements, while providing a highly visible "showcase" which will speed acceptance among personnel.

It is not yet possible to use solar thermal technology in tactical situations. The defense mission capability must be maintained. Data on the reliability, availability, maintainability and dependability of solar thermal equipment is necessary before these systems can be purchased under normal procurement procedure. Before the military institutes a new system it must be shown that a significant increase in capability is required, is achievable, and affordable. The multi-fuel aspect of solar thermal technology may fulfill that requirement and should be emphasized.

To institute an FPUP-type program, Congressional action may not be necessary--an interagency agreement would suffice.

The normal DOD procurement cycle requires operational and maintainability data before any system may be purchased. Statistically relevant data that the DOD has compiled are usually required, although DOD may accept credible data produced by other labs.

The resistance to change that exists everywhere in human nature is also present within the Department of Defense. In order for acceptance of solar thermal technology by society, education is necessary.

Human nature can work in favor of solar development if incentives accompany the development and installation of solar equipment. For example, experience in California has shown that tax shelters and incentives, if they are large enough, permit solar technology to be implemented solely for financial reasons.

Government involvement is necessary for the implementation of solar thermal technology to occur at an accelerated pace. The market place cannot do it alone. Loan guarantees and tax incentives have to exist.

If a commitment to solar technology exists in this country, it should be put into writing, and both DOE and DOD should be made aware of it.

BARRIERS

- TIME FRAME ACCELERATION
- CONGRESSIONAL POLITICS
- "SLOWNESS" AT DOE
- LACK OF USER INFORMATION
- LACK OF INFRASTRUCTURE
  - WORK FORCE
  - FINANCING
  - SMALL BUSINESS (COMPETITION)
  - LEGAL/REGULATORY UNCERTAINTY
- SOCIAL AND DOD ACCEPTANCE MODELS
- SUBSIDY OF OTHER FUELS

NEW LEGISLATION

- DOD PROVISIONS
  - PROGRAM PLAN
  - DATA BASE DEVELOPMENT
  - FPUP ANALOGOUS (LIFE CYCLE COST IN 3-4 YEARS)
- SMALL BUSINESS
  - MARKET SURVEY SUPPORT
- GOVERNMENT STUDIES
- INVOLVE STATE & LOCAL GOVERNMENTS
- INVOLVE UTILITIES
- TECHNOLOGY DEVELOPMENT
  - FUELS AND CHEMICALS
  - HYBRID CAPABILITIES

NON-LEGISLATIVE

- INDUSTRY
  - PUBLIC RELATIONS
  - POSITION PAPER
  - POLITICAL PRESSURE
- DOE
  - PROGRAM PLAN
  - STREAMLINE PROCUREMENT
  - CLEAR UP PATENT STATUS

MYPP

- A COMPREHENSIVE MULTI-YEAR PROGRAM PLAN FOR DEVELOPMENT AND COMMERCIALIZATION OF SOLAR THERMAL TECHNOLOGIES MUST BE PRODUCED AND APPROVED.

- KEY ELEMENTS
  - GOALS--RELATIVE TO NATIONAL GOALS
  - IDENTIFICATION OF MARKETS
  - STRATEGY--STEP-BY-STEP APPROACH
  - PLAN FOR INDUSTRY/DOE/DOD, ETC. INTERACTION
  - KEY RESPONSIBILITIES
  - SCHEDULES/RESOURCES

- 6-MONTH SCHEDULE TO APPROVAL

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