SOLAR 2000

A Collaborative Strategy

Volume I

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Office of Solar Energy Conversion
United States Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

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Notice

Foreword

SOLAR 2000 is truly a collaborative strategy, from its conception and evolution, to its final implementation. The SOLAR 2000 strategy grew out of a consultative process involving the Department of Energy, the solar and biomass industry, the research community, electric utilities and other users, regulators and policy-makers in the state and federal governments, and the national laboratories.

I want to express my deepest appreciation to all of the dedicated individuals who contributed toward building SOLAR 2000 into a comprehensive strategy ready to guide our efforts in making U.S. photovoltaics, solar thermal electric, and biomass electric technologies significant contributors to the energy mix of the nation and the world.

SOLAR 2000 is an aggressive strategy which will require all of us to work in partnership to achieve its goals. I look forward to working with all of you in the coming years to achieve our common interests of increased energy security, a strong and competitive solar and biomass industrial base, and a cleaner environment.

Robert H. Annan
Director
Office of Solar Energy Conversion
United States Department of Energy
Washington, D.C.

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*Refer to **VOLUME II - SOLAR 2000 APPENDICES** for details regarding Technology Development and Validation; Milestones; Summary of Cost of Electricity Screening Curves; and Cost Analysis Assumptions.*

ACRONYMS

ASTAE	Asia Technical Alternative Energy
APPA	American Public Power Association
BPA	Bonneville Power Authority
BPP	Biomass Power Plantation
CAAA	Clean Air Act Amendments
CC	Combined Cycle
COE	Cost of Electricity
CORECT	Committee on Renewable Energy Commerce and Trade
CR	Central Receiver
DAC	Design Assistance Center
DFSS	Dedicated Fuel Supply System
DOD	Department of Defense
DOE	Department of Energy
DSM	Demand-Side Management
EIA	Energy Information Association
EEI	Edison Electric Institute
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EXIMBANK	Export/Import Bank
FBC	Fluidized Bed Combustion
FERC	Federal Energy Regulatory Commission
FINESSE	Financing Energy Services for Small-Scale Energy-Users
GEF	Global Environmental Facility
GW	Gigawatt (10^9 watts)
IEEE	Institute for Electrical and Electronics Engineers
IFREE	International Fund for Renewables and Energy Efficiency
IGCC	Integrated Gasification Combined Cycle
IPP	Independent Power Producers
IRP	Integrated Resource Planning
MW	Megawatt (10^6 watts)
NAESCO	National Association of Energy Service Companies
NARUC	National Association of Regulatory Utility Commissioners
NASEO	National Association of State Energy Officials
NEPA	National Environmental Policy Act
NERC	North American Electric Reliability Council
NES	National Energy Strategy
NREL	National Renewable Energy Laboratory
NWEA	National Wood Energy Association
ORNL	Oak Ridge National Laboratory
OSEC	Office of Solar Energy Conversion
PG&E	Pacific Gas and Electric
PGI	Power Generating Inc.
PMA	Power Marketing Authority
PUHCA	Public Utilities Holding Companies Act
PURPA	Public Utilities Regulatory Policies Act
PV	Photovoltaics
PVMaT	Photovoltaics Manufacturing Technology Initiative
PVUSA	Photovoltaics for Utility Scale Applications
R&D	Research and Development
RD&D	Research, Development and Demonstration
SCE	Southern California Edison Company
SEIA	Solar Energy Industries Association
SERDP	Strategic Environmental Research and Development Program
SNL	Sandia National Laboratories
ST	Solar Thermal
STIG	Steam Injected Gas Turbine
T&D	Transmission and Distribution
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
US/ECRE	U.S. Export Council for Renewable Energy
WAPA	Western Area Power Administration

EXECUTIVE SUMMARY

Within the U.S. and overseas, a number of events are unfolding in energy and related sectors that will open the door for a host of new technology solutions. Prevailing trends in the energy sector which will lead to greater commercialization of solar electric technologies include the need for new electricity generating capacity, heightened awareness of the environmental impacts associated with energy use, greater attention to energy efficiency and integrated resource planning, and a strengthened emphasis on technology transfer and commercialization.

Solar electric technologies -- biomass electric, photovoltaics, and solar thermal electric -- will play a significant role in meeting electricity requirements in both the U.S. and overseas. *They offer utilities and other end-users a full array of options for virtually every requirement spanning baseload, intermediate, peaking, demand side management, fuelsaver, and remote applications. Today, for the bulk of applications, these technologies are not yet routinely considered in mainstream energy planning decisions. Yet, with improved technology performance, lower costs, and elimination of existing market and institutional barriers, solar electric technologies will make a greater contribution to the nation's energy mix.*

Considerable opportunities exist for solar electric technologies in several value-added markets -- applications that yield benefits over and above pure cost consideration. *Initially, solar electric technologies will penetrate those value-added markets which exhibit favorable conditions for their application. These primary markets exist in regions which have the following characteristics: (1) plentiful solar and biomass resources; (2) small incremental capacity requirements; (3) strict fossil fuel emission regulations; and (4) the high cost, or lack of transmission lines. Moreover, as utilities strive to achieve greater energy efficiency and comply with new increasingly stringent environmental regulations, solar electric technologies are finding many more potential applications in supplementing or replacing conventional energy technologies.*

Through SOLAR 2000, the U.S. Department of Energy's (DOE) Office of Solar Energy Conversion (OSEC) proposes a collaborative strategy to accelerate the adoption of biomass electric, photovoltaic, and solar thermal electric technologies by utilities and other users. *This strategy is founded on a partnership with each of the key players in the field, including the U.S. solar electric industry, utilities, regulators, and federal and state agencies. SOLAR 2000 will facilitate the development of the U.S. industrial and technological base to provide proven world class products for a range of electric sector needs. It will also increase the capability of utilities and other users to identify, evaluate, and adopt these technologies as they become viable for particular applications. SOLAR 2000 centers around three major elements which build upon the technological progress of the 1980s to address the growing energy needs of the 1990s:*

- ***Technology Development and Validation.*** *By advancing solar electric technologies through collaborative research, development, and demonstration (RD&D), SOLAR 2000 promotes more reliable, durable, and cost-competitive systems for the marketplace. This component includes synchronizing the RD&D effort with the needs of utilities and*

other customers, expanding the availability of resource data, and improving manufacturing processes and system performance.

- ***Market Conditioning.*** *By laying the groundwork with potential buyers, SOLAR 2000 will work in collaboration with other stakeholders to help overcome the remaining obstacles to market acceptance of solar electric technologies. This will be accomplished in an effort to enhance technology awareness through targeted education campaigns, and capture technology benefits by setting in place an improved policy and regulatory framework.*

- ***Joint Venture Projects.*** *SOLAR 2000 will facilitate joint activities between industry, utilities, and other end-users that will lead to implementation of commercially viable projects. Through joint ventures, inherent risks associated with these new technologies are reduced, and the likelihood of significant project investments are increased. OSEC can participate in a number of collaborative arrangements to support project development, industry scale-up, and enhanced penetration of the national and international energy marketplace.*

SOLAR 2000 heralds a new era for DOE. *In the past decade the federal government and private industry have invested over $2 billion in solar electric research and development (R&D). The result is a range of products and services available today, with a host of next generation technologies ready to come on-line in the upcoming decade. Through SOLAR 2000, DOE, in conjunction with other stakeholders, will work to aggressively bring these technologies into the marketplace. Although DOE will continue to support a strong basic and applied technology R&D program, it places new and equal emphasis on market conditioning and joint-venture project development -- a commitment needed to ensure that these technologies become serious energy contenders. Without these efforts, prior public and private investments in the technologies will be lost; opportunities for environmentally sound, cost-competitive energy options will be reduced; and foreign competition will once again succeed in capturing a product market initiated by the United States.*

The National Energy Strategy reports that about 100 GW of new generation will be needed in the U.S. in the 1990s, with an additional 90 GW in the first decade of the next century. Another 500 GW will be needed overseas in the 1990s. DOE expects SOLAR 2000 will lead to the installation of over 8 GW worldwide of U.S. solar electric technologies by the end of the decade. While this represents a 130% increase in the currently installed capacity of solar electric technologies, it is but a small fraction of the 600 GW expected to be installed worldwide by the year 2000. ***SOLAR 2000 represents an ambitious effort augmented by the full support and commitment of the DOE. Through this coordinated and collaborative effort, industry, stakeholders and the nation as a whole will reap the full advantages of solar electric technologies.***

I. INTRODUCTION

Setting the stage for SOLAR 2000 is a need to understand the market opportunities for solar electric technologies, the current and projected status of the technologies, the configuration of the U.S. solar electric industry, and the role of the U.S. Department of Energy (DOE) Office of Solar Energy Conversion (OSEC). This section addresses each of these areas and provides the framework in which SOLAR 2000 will operate. Subsequent sections identify the specific goals, objectives, and strategy for this program; planned solar energy conversion activities; and the resources required to successfully carry out SOLAR 2000 initiatives.

THE MARKETPLACE: OPPORTUNITIES FOR SOLAR ELECTRIC TECHNOLOGIES

Electricity Generation Capacity Needs

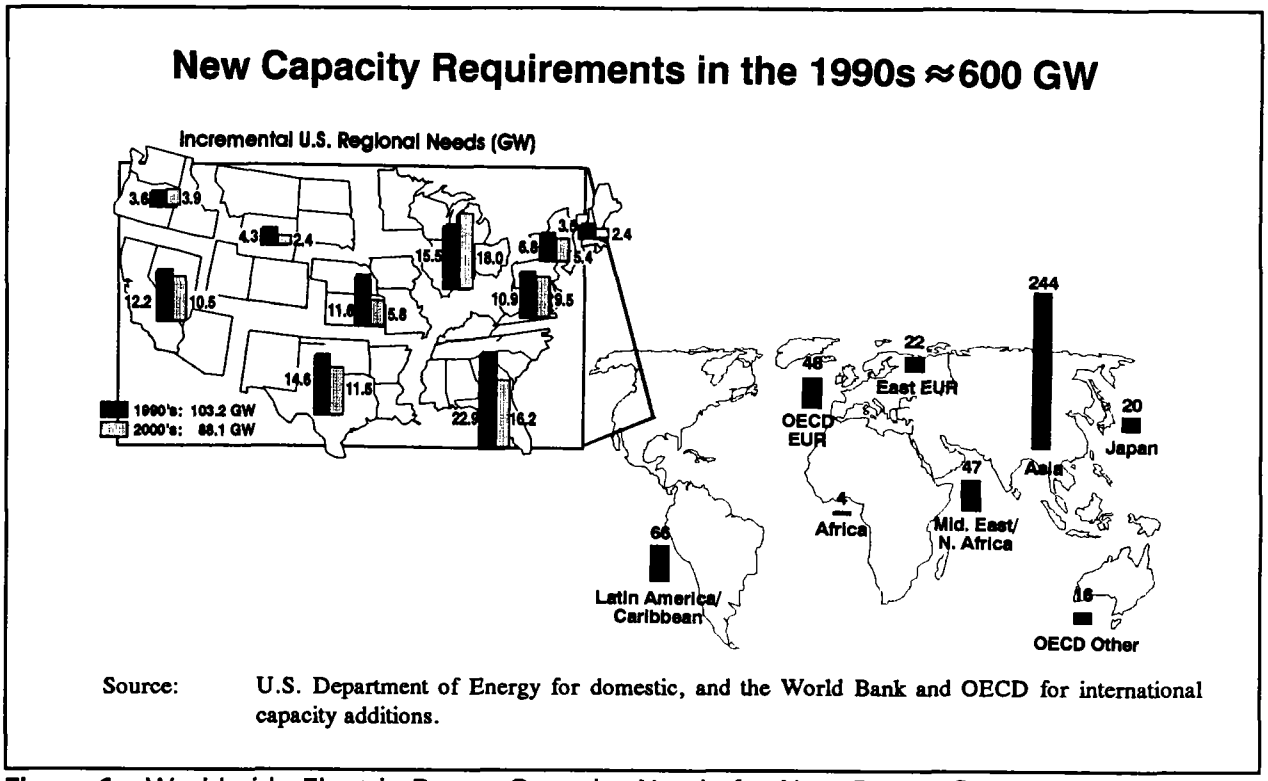
In total, nearly 600 GW of new generating capacity may be required worldwide between 1990 and 2000, requiring an investment of around $600 billion (Figure 1).[1,2,3] In the U.S., the National Energy Strategy estimates a need for over 100 GW of new generating capacity in the 1990s and nearly 90 GW in the first decade of the next century. Approximately 75 percent of the new capacity in the U.S. is expected to be installed by utilities, 20 percent by independent power producers, and about 3 percent is planned to be jointly-owned. Of the utility plants planned, 18 percent will be primarily small hydro, non-hydro renewables, multi-fuel units, and several that are as-yet undetermined or unplanned.[4] The non-utility generators include a mix of all fuel types, except nuclear.

In the international marketplace, a need for nearly 500 GW of generating capacity is anticipated in the next 10 years. Developing countries alone will require about 350 GW of capacity, with India and China accounting for over half of this increase. If no other alternatives are made available, nearly 45 percent of the new capacity is expected to be coal-based and 36 percent will be large hydro. Oil and gas-fired plants, including steam, combustion turbines, combined cycle, and diesels account for 13 percent of the new capacity.

In due course, solar electric technologies will routinely capture an increasing share of this huge market. During the 1990s, solar electric technologies will be used in value-added markets where customers will benefit from their special advantages. These markets are important -- they help build the necessary experience base and help establish the infrastructure needed for the large-scale deployment of these technologies. In addition, these value-added markets build confidence among customers that the technologies can provide reliable, cost-effective, and clean power.

Value-Added Markets for Solar Electric Technologies

Underscoring the demand for new generating capacity are emerging political, business, environmental, and technological trends that indicate enhanced opportunities for efficient and environmentally acceptable power systems such as solar electric technologies.



Source: U.S. Department of Energy for domestic, and the World Bank and OECD for international capacity additions.

Figure 1 - Worldwide Electric Power Capacity Needs for New Power Generation

Current and pending regulatory and legislative actions will encourage the expanded use of renewable energy technologies. The National Energy Strategy unveiled in 1991 called for enhanced R&D for alternative energy technologies, thereby demonstrating a long-term federal commitment to these technologies. More opportunities are emerging as a result of growing environmental concerns. These are exemplified by the Clean Air Act Amendments of 1990, another 100 environmental legislative initiatives, and numerous state-sponsored environmental regulations.[5] Changes to the Public Utilities Regulatory Policies Act (PURPA) in combination with proposed Public Utilities Holding Company Act (PUHCA) modifications are also capable of expanding the role of solar electric technologies.[6] In addition, the Federal Energy Regulatory Commission (FERC) and state regulators are recognizing that existing regulations do not provide utility incentives for investments in solar electric technologies.[7] The political climate is especially favorable for solar electric technologies, as demonstrated by a number of recent legislative actions. They include, P.L.102-136 which appropriated $6 million for PV projects in the Department of Defense; a number of Congressional proposals for utility-scale PV demonstrations;[8] a joint venture program for biofuels energy systems;[9] and a renewable electricity production tax credit for new capacity included in several congressional proposals.

The changing character of the electric utility industry, and its openness to considering alternate approaches for delivering electricity services will create opportunities for solar electric technologies. Utilities are beginning to deliver electricity services through a mix of central generation and transmission, distributed generation, and off-grid power supply. There is a greater emphasis on integrated resource planning, use of modular alternative energy

technologies, energy efficiency, and demand-side management (DSM). Moreover, non-utility wholesale power generating groups, including utility business subsidiaries, are showing increased interest in alternative energy technologies. These groups can respond more readily to new opportunities than can regulated utilities as they are less constrained in their choice of generating technology, legal and administrative requirements, and risk taking.

The modular characteristic of solar electric technologies is especially valuable. For utilities needing small incremental capacity additions, the opportunities for solar electric technologies are enormous. For more than two-thirds of the utilities in the U.S., the annual growth in capacity requirements is expected to be less than 100 MW per year, with more than 88 percent of the utilities having requirements of less than 250 MW per year (see Figure 2).

Solar electric technologies can be applied to the repowering or co-firing of existing plants. They are highly useful in situations where emissions regulations constrain the use of fossil technologies. An estimated 340 GW of currently installed capacity will be repowered, or the life extended in the next 20 years.[10] In addition, 160 GW of existing capacity will pass its 50th birthday in the period 2000 to 2010.[11]

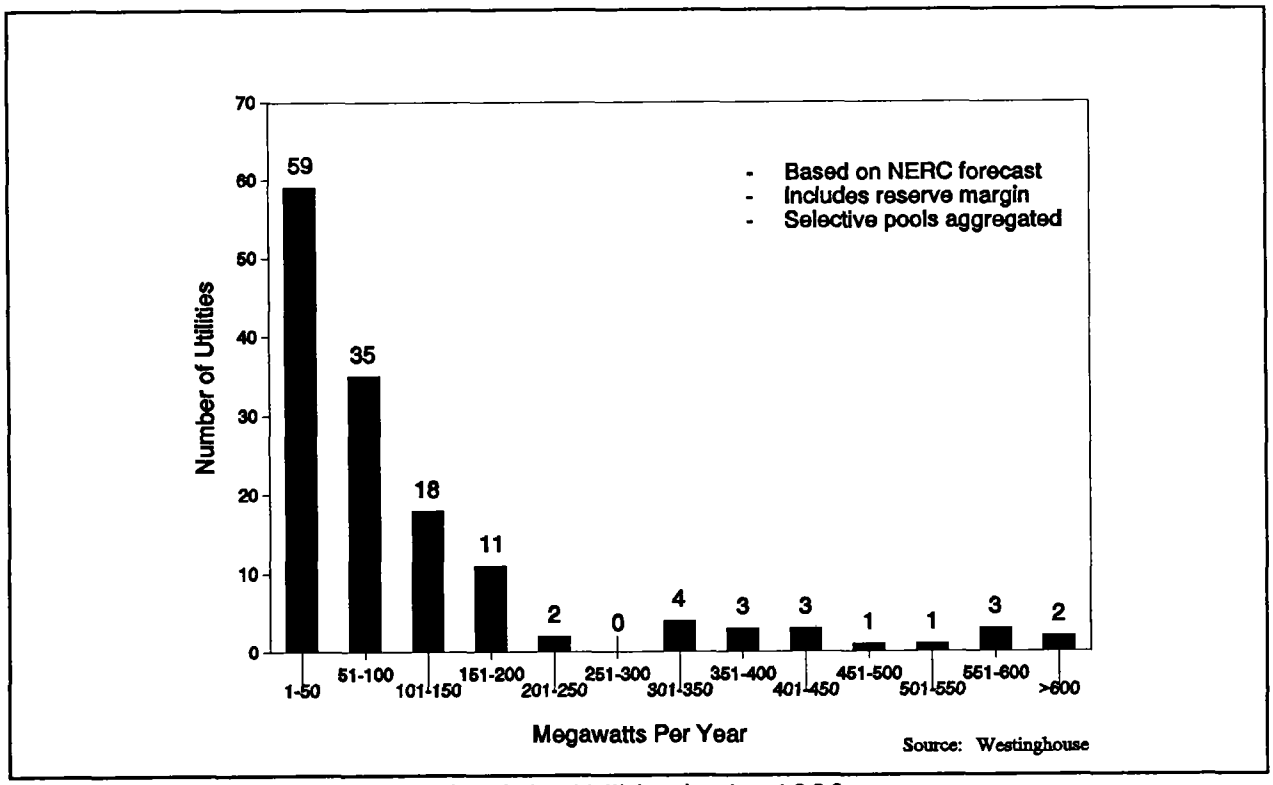


Figure 2 - Annual Capacity Needs of the Utilities in the 1990s

Value-added opportunities exist for distributed generation and off-grid solar electric technologies. These technologies can be used for peak load shaving or voltage support, and additionally, where the lack of or high cost of grid extension precludes connections to centrally generated power.[12,13,14] Electric utilities in the U.S. use PV power systems as a cost-effective alternative to grid extension for isolated loads such as stock watering or remote homes.[15] They are also using PV to power small loads within their service territories. These include obstruction/warning lights, sensors, sectionalizing switches, cathodic protection, isolated substation service, meteorological stations, and lighting.[16]

The opportunities are even greater in developing countries, particularly in areas with excellent solar and biomass resources. There is a growing awareness of the potential for solar electric technologies by the decision-makers in host countries and multilateral lending agencies. The World Bank has established an Asian Alternative Energy Unit to help identify and prepare alternative energy projects for financing. Large PV projects in Zimbabwe and India are expected to be implemented with Global Environmental Facility (GEF) cofinancing. The GEF has already financed a number of biomass power projects in the Caribbean and Africa.

Off-grid modular solar electric systems are capable of meeting power generation needs and are appropriate for many of the 1.7 billion people living in unelectrified rural communities in developing countries. Currently, the power requirements of these communities are met by primary batteries, kerosene (for lighting), and gasoline and diesel generators. The total remote electric power requirements in these countries are huge: 10 million small diesel generators (less than 200 kW) are in use in the high solar insolation areas around the world, with 2 million new generators sold annually.[17]

THE TECHNOLOGIES

Solar electric technologies increase the choices available to developers and investors seeking to provide their customers with reliable, high quality power at the lowest cost. Table I displays an array of competitive solar electric technologies which are available to meet power requirements in the next decade. From a technical viewpoint, biomass electric systems are suitable for baseload and intermediate load power generation in the east and northwest U.S. Solar thermal electric technologies are suitable for serving intermediate loads in the west. Both PV and solar thermal electric systems offer potential in the peaking range. Modular generation units such as PV or solar thermal dish generators are available for demand-side management, and for remote off-grid power markets. They are also well suited for distributed grid interactive applications owned by utility/independent power producers (IPP).

TABLE I - SOLAR AND BIOMASS TECHNOLOGIES FOR MEETING POWER GENERATION NEEDS

UTILITY/USER POWER SUPPLY NEEDS	NEAR TERM COMMERCIAL APPLICATIONS (PRE 2000)	GROWTH AREAS (POST 2000)
Intermediate Scale Power Stations (100-200 MWe)	• Parabolic trough steam systems • Combined cycles with biomass (pyrolysis oils) • Biomass cofiring	• Central receiver solar electric systems • Biomass integrated gasification combined cycle
Modular Scale Power Stations (< 100 MWe)	• Repowering existing biomass steam systems • Parabolic trough steam systems	• PV power stations • Steam Integrated Gas Turbine (STIG)/biomass pyrolysis oil systems • STIG/biomass gasifier systems
Load Center/Demand-Side Power Options (< 10 MWe)	• PV and small dish/Stirling power generation for T&D support • Building integrated PV systems for peak demand reduction • Biomass direct fired gas turbine cogeneration	• Distributed PV and dish/Stirling peaking power stations
Off-Grid Applications	• Stand-alone/hybrid PV • Stand-alone/hybrid dish/Stirling	

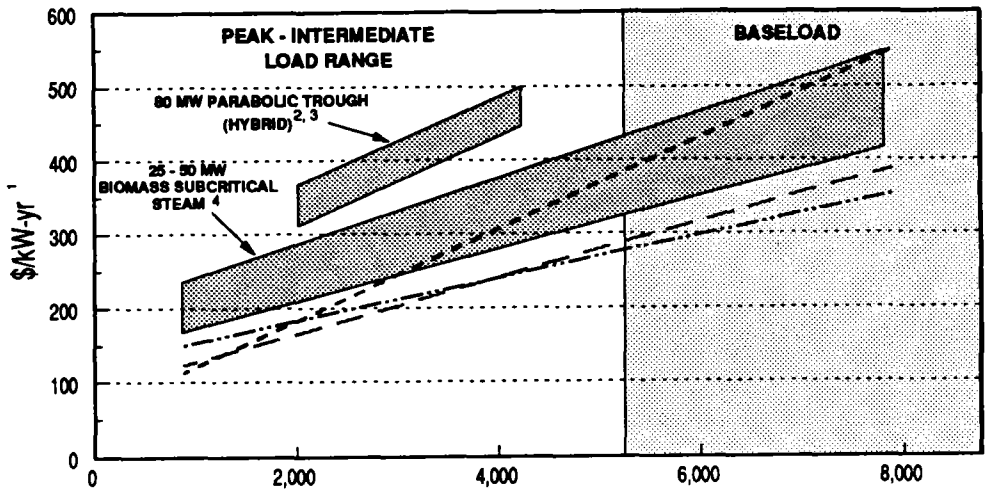
COST COMPETITIVENESS OF SOLAR ELECTRIC TECHNOLOGIES

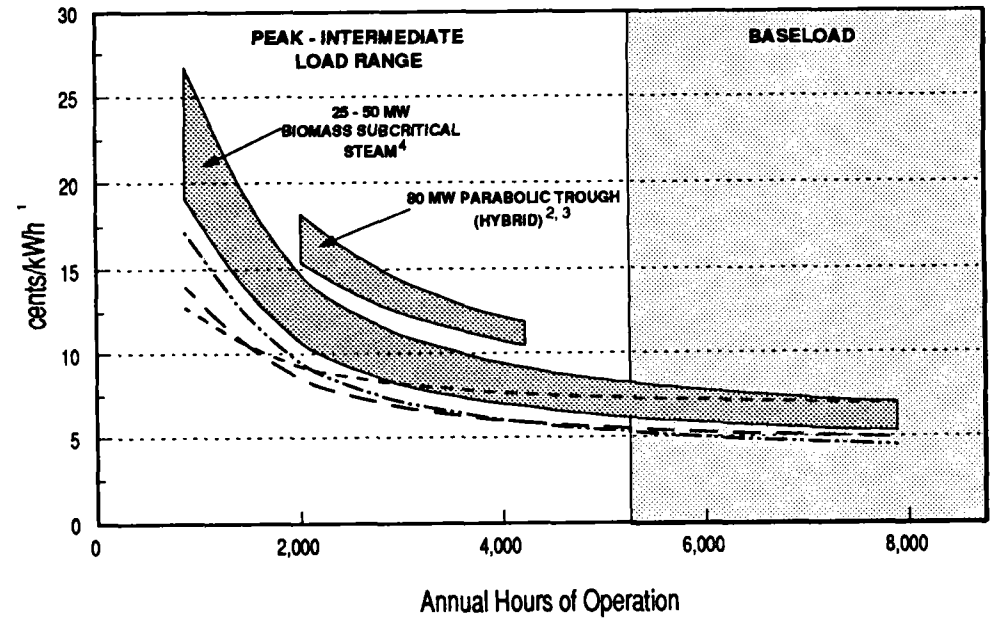
The cost competitiveness of solar electric technologies with respect to conventional power generation options was evaluated using the Electric Power Research Institute (EPRI) revenue requirements method.[18] In addition to cost, utilities also considered the reliability and availability of the power plant, as well as environmental impacts, in making technology selections. The following analyses use the environmental cost adders developed by the State of Nevada to account for the environmental impacts of each technology. However, environmental cost adders were not used for the "Current Supply Options" analyses as the use of these adders is not a common practice today.

Current Supply Options

In Figure 3, screening curves for new plants with the economics of utility ownership are provided for current technology options. Screening curves plot the annual levelized cost of owning and operating power plants as a function of duty cycle (annual hours of operation) to provide a preliminary indication of the competitiveness of generating options over a wide range of demand schedules. For comparison purposes, Figure 3 shows annual levelized costs in both $/kW-yr and cents/kWh. Both curves accurately depict the relative cost effectiveness of each plant. The $/kW-yr plot is typically used by utility planners to assess the annual revenue requirements for the power plant. The cents/kWh chart indicates the production cost of the plant. Both charts are used by utilities, however, the cost/kW-yr chart is more commonly applied in making technology choices. (For further explanation of screening curves and the relationship between $/kW-yr and cents/kWh, see Volume II, Appendix III.)

Current choices of commercial solar electric plants for utility applications have been limited to biomass-fired and solar parabolic trough steam turbine installations. Commercial solar plants depicted in Figure 3 are shown as cost bands due to the wide variation in cost and performance depending on many factors including quality of the resource, and availability of tax and regulatory incentives. These options are not generally competitive with the conventional power options based on traditional utility accounting practices. However, the solar parabolic trough plants on the Southern California Edison (SCE) grid and the 6,000 MW of small capacity wood/waste-fired plants throughout the country are proof that opportunities abound. Innovative financing methods, good resource availability, regulatory and financial incentives, and attractive electricity buy-back rates helped make these projects profitable to the investors.





40 MW NATURAL GAS SIMPLE CYCLE GAS TURBINE [2]

600 MW PULVERIZED COAL SUBCRITICAL STEAM [2]

167 MW NATURAL GAS COMBINED CYCLE GAS TURBINE [2]

* Reference appendices for detailed assumptions.
1. Costs are in levelized 1990 dollars.
2. based on NES fuel prices.
3. based on Daggett, CA insolation.
4. based on $ 2.00/MMBtu fuel price.

Figure 3 - Utility Plant Options for 1991

Modular Power Plant Options for the 1990s

Technology improvements, use of comprehensive valuation methods, and integrated resource planning will alter the planning picture for new generation sources. Figure 4 shows screening curves for modular plants (less than 100 MW). Plants of this size are attractive to utilities which need to make incremental additions to system capacity while minimizing investment risks. These curves show both the effects of projected increases in gas prices and valuation of environmental externalities on the cost of generation. By 1998, a number of new solar electric technologies are expected to be commercially viable. Small, high-efficiency steam-injection gas turbines can be directly coupled with biomass gasifiers or fired with biomass-derived pyrolysis oils to provide economical power throughout the intermediate and baseload range. Hybrid solar-gas plants using dish concentrators, coupled with high-efficiency Stirling engines or parabolic trough steam will also be competitive. Small photovoltaic power stations are likely to be a competitive player, particularly in power markets where zero emissions are desirable. As noted previously, special market conditions could make PV very attractive in other locations or applications.

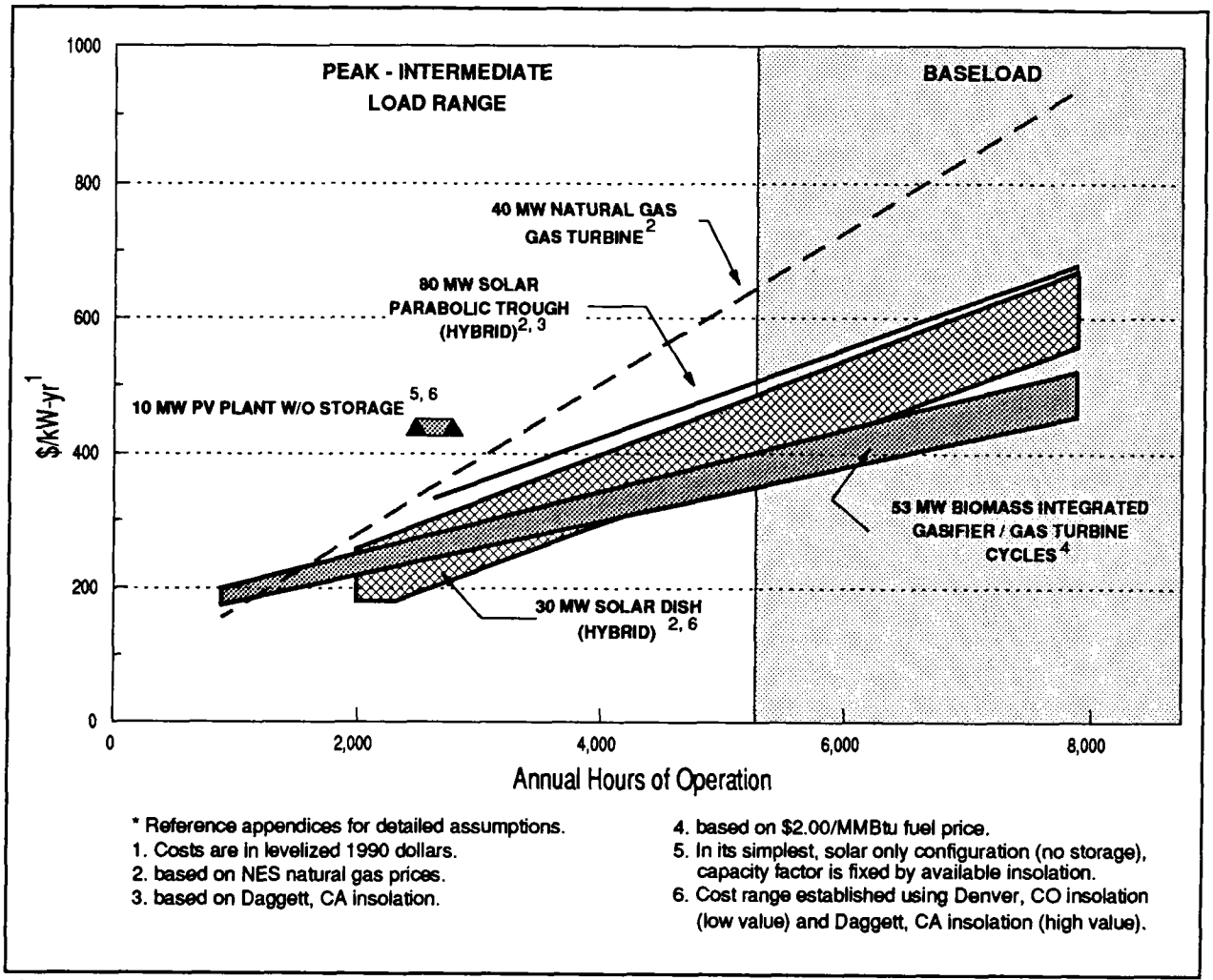


Figure 4 - Screening Curves for 1998 Modular Power Plants (< 100MW)

Meeting Load Growth with Demand Side Power Supplies

Utilities charge some customers a premium for power used during periods of peak demand to encourage load control (demand side management), recoup the expense of providing power for peak loads, and delay the construction of cost-intensive greenfield power plants. Although rates for power consumption during times of peak demand are utility specific, customers can expect to pay 2 to 4 times the standard non-peak rates. In addition to conservation measures and load shifting techniques, such as ice storage, the use of on-site peaking power generators can be a cost-saving option. Furthermore, since generation is the business of utilities, power companies could operate or assist customers in operating on-site generators designed to provide standby generation capability and a new distributed source of dispatchable power. Figure 5 compares the cost of electricity for on-site power generation and ice storage for peak demand reduction in commercial and institutional buildings. Small PV and dish Stirling power supplies will compete with diesel generators, with the added advantage of zero emissions (or very low emissions for hybrid configurations) and quiet operation.

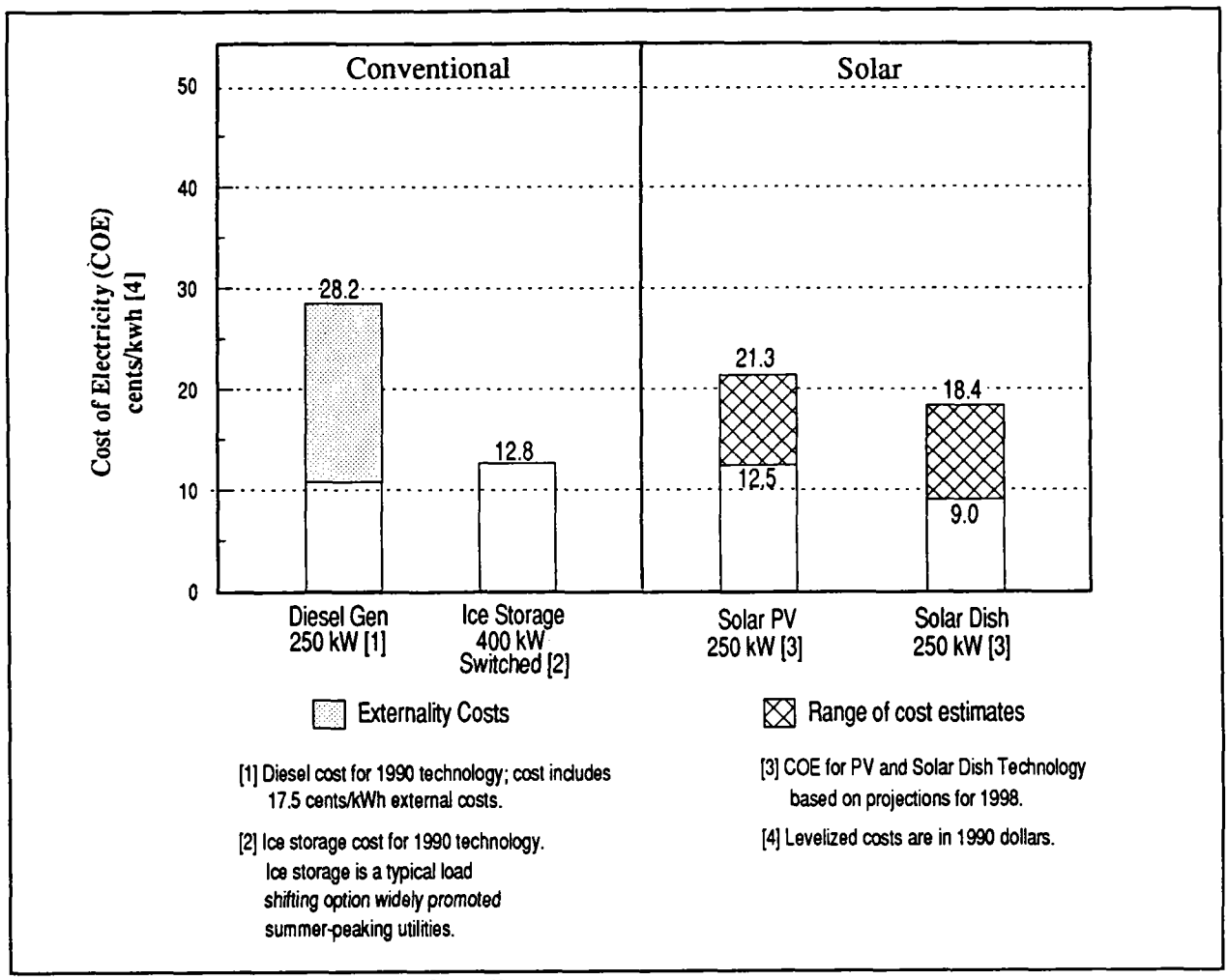


Figure 5 - Demand Side Power Supplies

Transmission and Distribution (T&D) Grid Support

For load centers where demand growth has strained local T&D capabilities, the conventional approach has been to upgrade or add substations to meet new requirements. In some cases, the substations are upgraded only to meet peak loads that occur for a short duration. Where there is good insolation, solar electric technologies can be used to meet these peak loads. Avoided utility costs accrue both to savings in generation, T&D equipment capacity additions/ improvements, as well as to increased reliability of customer service. As demonstrated in Figure 6, PV and dish systems offer cost-effective alternatives to substation upgrades if peak loads coincide with solar insolation peaks. For these applications it would be desirable to provide the supplemental power with generators that can operate essentially unattended. PV and dish Stirling can provide this kind of capability. Although the comparative costs for PV and dish Stirling systems in Figure 6 are those projected for the post-1995 time frame, Pacific Gas & Electric (PG&E) reported that current PV systems could be marginally competitive today in optimum locations.

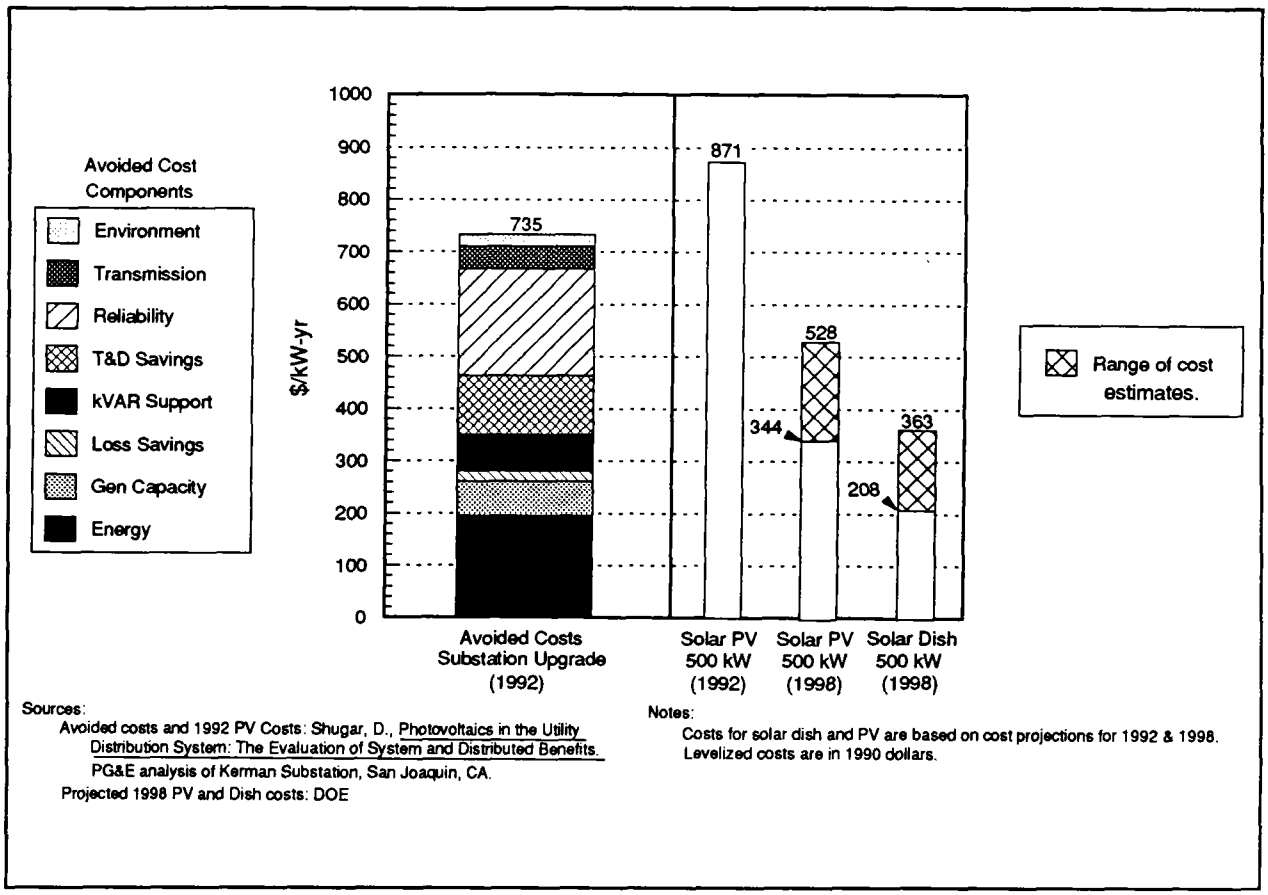


Figure 6 - Distributed Power Supplies - An Option to Substation Upgrade

Intermediate-Scale Power Plant Options for the 1990s

In Figure 7, screening curves for intermediate scale plants are compared. At this scale, central receivers and biomass-fired combined cycles (i.e., integrated gasification and intercooled steam-injected gas turbine) are expected to be competitive for intermediate and baseload duty cycles. The zero emission characteristics of the solar thermal central receiver plant is likely to be an important factor in competitive bidding for a number of southwestern utility service areas. Furthermore, storage system capabilities associated with the central receiver technology offer the ability to generate power at any time of day or night. One biomass power option that may become commercially available by the mid 1990s involves the thermochemical conversion of solid biomass into liquid fuels (comparable to a residual oil). These virtually sulfur-free fuels can be easily transported beyond the ranges normally associated with practical wood fuel procurement and can be used, potentially, in a number of high efficiency gas turbine-based cycles.

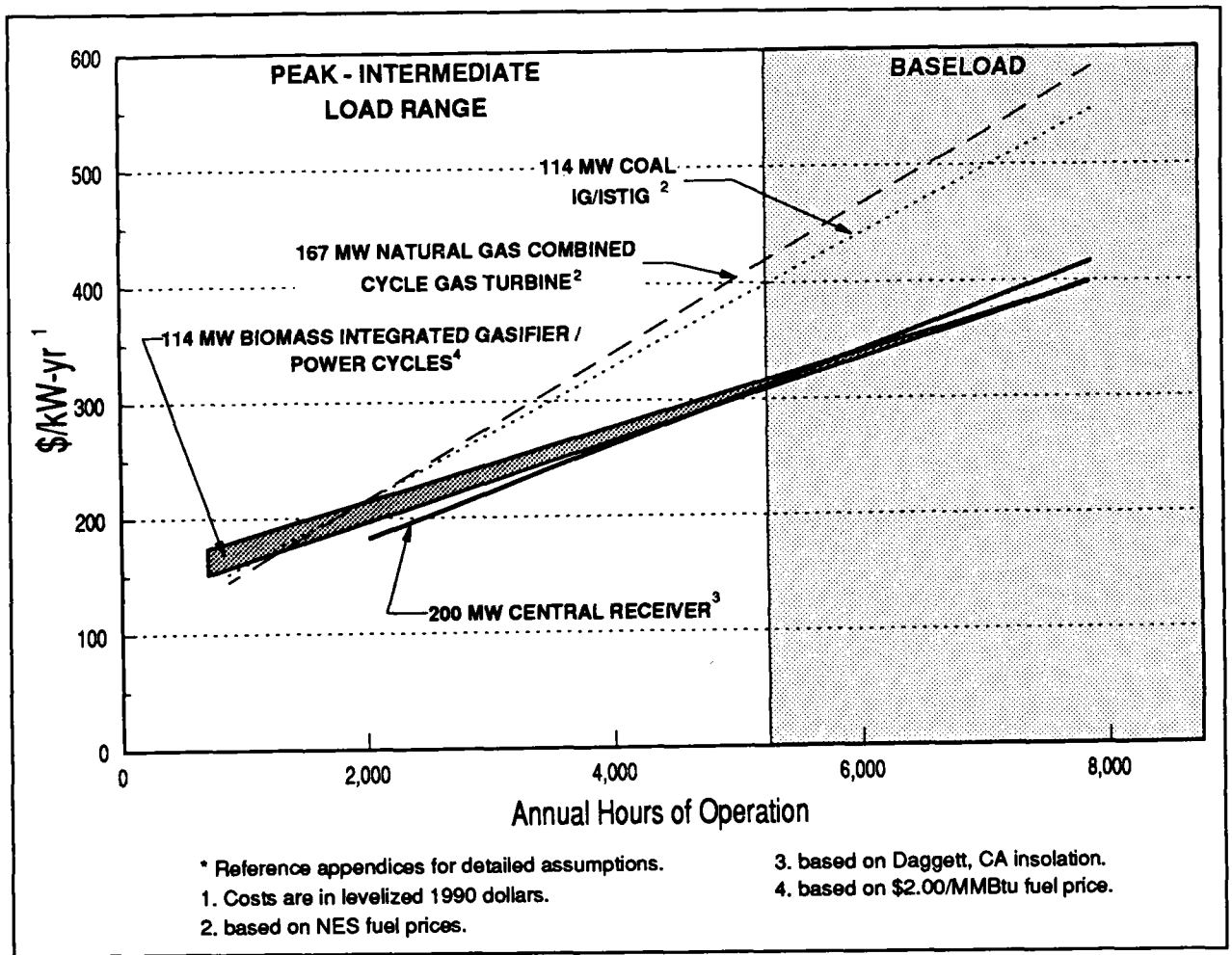


Figure 7 - Screening Curves for 1998 Intermediate Scale Power Plants (100-200 MWe)

Providing Power to Remote Locations

Areas not currently serviced by utility grids -- remote areas of industrialized nations and most rural areas of the developing world -- are prime candidates for modular renewable energy power systems. Although the total electric power requirements in developing countries are substantial, the power needs of most individual rural communities without electric service are modest. Their principal commercial energy sources are batteries, kerosene (for lighting), and gasoline and diesel generators. The modularity, ease of maintenance, and independence from fuel supplies makes solar electric technology such as PV and dish electric systems ideally suited for remote and dispersed applications. Figure 8 indicates the economics of these systems relative to diesel generator sets and grid extension.

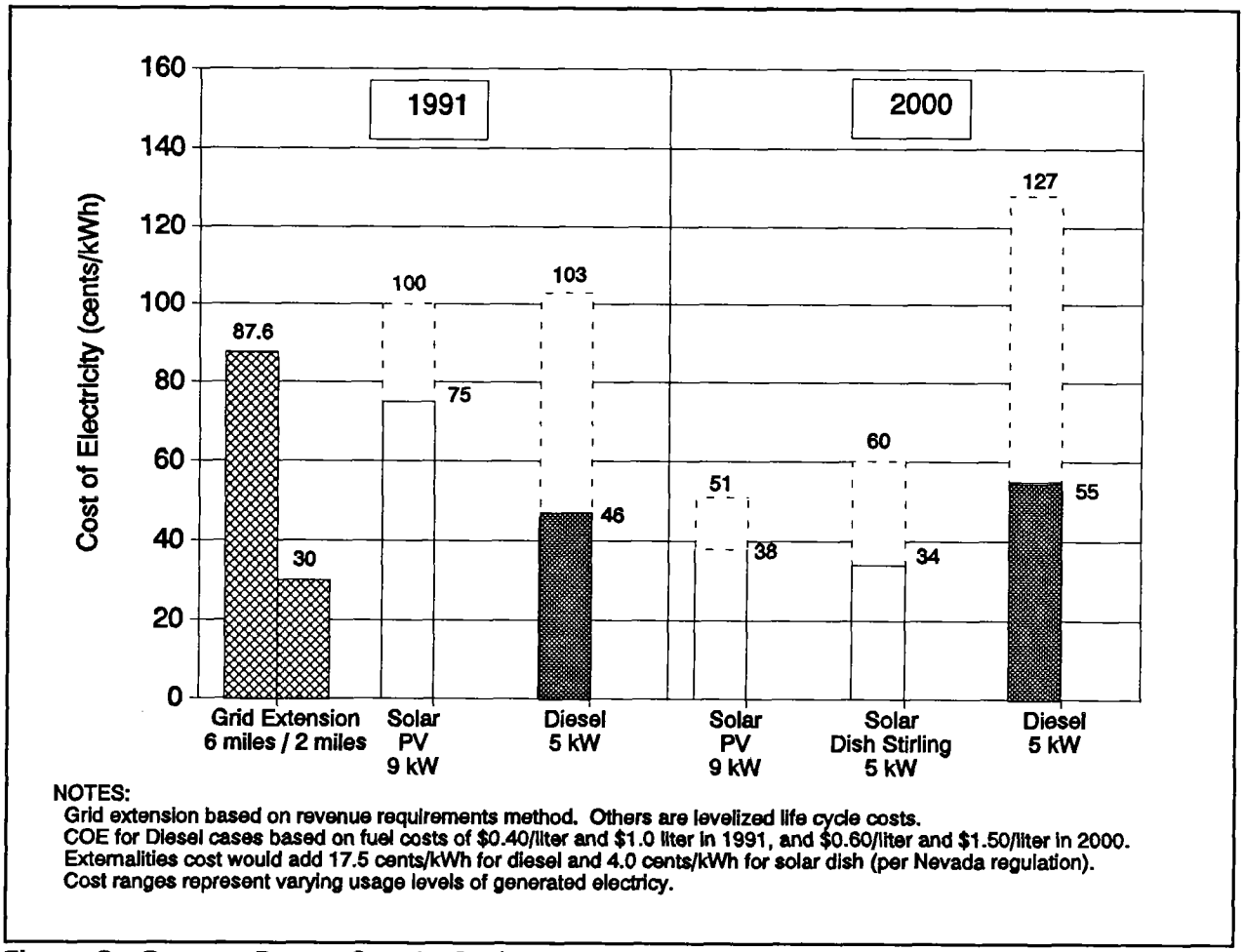


Figure 8 - Remote Power Supply Options

U.S. INDUSTRY: ITS PRODUCTS AND SERVICES

Solar electric R&D investments over the last decade have helped establish an industrial base which supplies hardware as well as services including resource assessment, design and engineering, project evaluation and development, and operation and maintenance (Table II). The U.S. industry has achieved international leadership in research, product performance, and system operation in a number of energy markets. The industry ranges from small start-up ventures to divisions of Fortune 500 companies.

TABLE II - REPRESENTATIVE PRODUCTS AND SERVICES OF U.S. COMPANIES*

PHOTOVOLTAICS	SOLAR THERMAL	BIOMASS POWER
Cells	Concentrating Collectors	Boilers
Modules	Absorber & Reflective Coatings	Gasifiers (Pyrolysis units)
Support Structures	Absorber Tubes & Receivers	Turbines (Electric power plants)
Trackers/Controls	Pumps and Valves	Ash Handling Systems
Inverters	Controllers/Trackers	Feed Hoppers & Conveyor Systems
Batteries	Heat Transfer Fluids	Chippers & Skidders
Testing Labs	Heat Exchangers	Feller-Bunchers
Manufacturing Equipment	Support Structures	Pelletizers
Semiconductor Materials	Conversion Units (Engines)	Manufacturing Equipment
Power Conditioning Equipment	Test Facilities/Labs	
	Manufacturing Equipment	

SERVICES	END-USE EQUIPMENT
Resource Assessment	Water Pumps
Design	Lights and Refrigerators
Site Engineering	Battery Chargers
Installation	Telecommunications Equipment
Manufacturing	Modular Power Units
Testing and Monitoring	Remote/Off-Grid Power Equipment
Operation	
Environmental Impacts Analysis	
Training	
Information Dissemination	

* Turnkey and customized equipment, systems, and services available in each technology area.

The photovoltaic industry continues to experience phenomenal growth, with 1991 shipments of 55.3 MW representing an almost 20% increase from the previous year. The U.S. industry, with sales exceeding $100 million annually, continues to be the world leader in PV power sales. About 40 PV companies supply a complete range of services from cell fabrication, system engineering and installation, to construction of turnkey manufacturing plants. To date, almost 100 MW of U.S. PV systems have been installed worldwide. The principal market is off-grid remote power applications.

Today's solar thermal electric industry consists mainly of companies pursuing research, development and demonstrations (RD&D). The notable exception is Luz International Ltd. which operates 350 MWe of commercial power stations supplying peak power to the southern California grid. With the more recent entry of Cummins Power Generation and Detroit Diesel as investors in the next generation of dish Stirling systems, the timing for commercialization of this technology in the remote and distributed power generation markets in the U.S. and

worldwide could be as early as the late 1990's. These companies have extensive distribution channels in place for reaching markets for dish Stirling modules.

Through the 1980s, the U.S. biomass industry experienced significant growth, from 200 MW of capacity in 1979 to 6,000 MW by 1991, mainly due to PURPA and federal tax incentives. Most of these systems are smaller-scale independent power and cogeneration systems; however, two 50-MWe power stations are operated by utilities in Vermont and Washington. Today approximately 30 different companies are involved in developing biomass-fired power plants for sale to electric utilities or industrial facilities.

The solar electric industry is at a crossroads. On the positive side, there are encouraging signs due to better products entering the market, greater awareness among the customers regarding the potential of solar electric technologies, and stronger commitment toward environmentally cleaner technologies by state, federal and international agencies. On the downside, the boom-and-bust cycles of the past have caused industry to be reticent about embarking on a major investment program without stronger signals from the marketplace that there will be a stable expansion of the demand for solar electric technologies. U.S. industry has the capacity to respond to accelerated market needs. To achieve the necessary growth, additional capital must flow to firms; R&D achievements must be transferred to production lines; and production capacities need to be expanded. Furthermore, a number of regulatory, educational, market and financial factors beyond industry's control will need to be addressed through a variety of stakeholder actions. The recent financial difficulties of Luz exemplifies the predicament faced by many solar companies.

II. SOLAR 2000 GOAL & STRATEGY

The SOLAR 2000 goal is to accelerate the commercial use of U.S. solar electric technologies by the power sector and to assist the solar electric industry to meet growing energy demand in the near-, mid-, and long-term. The SOLAR 2000 collaborative strategy involves coordinated action on three fronts -- technology development and validation, market conditioning, and joint-venture project development -- which combine to address existing barriers in the electric power supply marketplace.

SOLAR 2000 will focus on national and international market sectors where U.S. companies believe that their competitive position needs strengthening. As depicted in Figure 9, the implementation *and* success of the SOLAR 2000 strategy depends on the cooperation and active participation of a number of key players including industry, researchers, users, investors, regulators, and policy-makers. Through a consultative and collaborative process, OSEC will work to make U.S. solar electric technologies widely acceptable throughout the world.

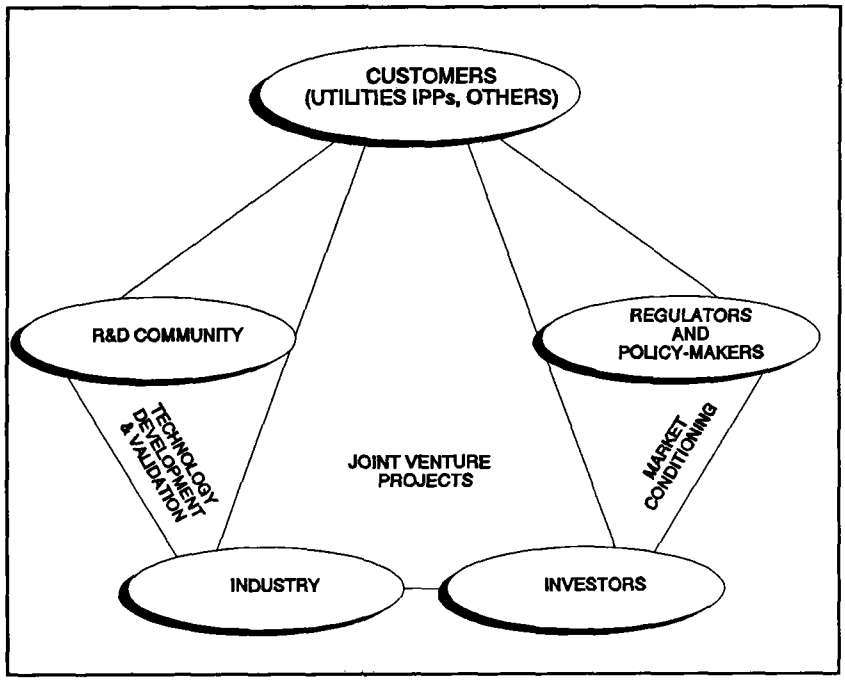


Figure 9 - SOLAR 2000 Strategy Framework

THE OSEC ROLE AND COMMITMENT

The OSEC role is to serve as a facilitator in breaking down barriers and bringing together producers and users in order to accelerate market penetration of solar electric technologies.

OSEC, with its strong ties to each of the stakeholder groups, as well as its national mandate on energy issues, can assist industry in promoting solar electric commercialization. Support for this OSEC position stems from its mission to look beyond the market, regulatory, and parochial constraints to consider energy planning in a framework that incorporates broader societal and economic concerns which benefit the nation as a whole (see sidebar). In this context, OSEC is in a position to promote technologies that yield benefits in areas of critical importance to the nation; namely, strengthening national energy security, improving environmental quality, ensuring a more secure energy supply, increasing energy efficiency, and promoting technology

transfer. They serve as the basis for OSEC's charter to aggressively pursue the objective of implementing PV, biomass-electric, and solar thermal systems in the marketplace.

THE NEED FOR GOVERNMENT SUPPORT: A PRIVATE SECTOR PERSPECTIVE

A strong government program is needed to address and share economic, technological, regulatory and other risks associated with solar conversion deployment. A recent tour of five of the more successful renewable energy firms highlights the important role that government has played in bringing these options to the marketplace.

- **Importance of Favorable Government Policies for Renewables.** The infant renewable energy industry has relied on federal, state, and local incentives (tax credits, accelerated depreciation, guaranteed buy-back rates) to reduce the risks associated with new technologies, spur the financing needed to demonstrate these options, and develop a proven track record. These incentives are required to reduce perceived risks and assist in leveling the playing field when competing with conventional power generation options.

- **Sensitivity of Renewables to Financing Sources.** The relatively high up-front capital cost for renewables as opposed to conventional power plants makes the financing of these systems an expensive component in their overall cost structure. Because of this sensitivity, the distinction between private investor versus utility financing is significant. Utility financing is often cheaper and the terms more attractive which improves the competitive position of some renewable power projects. Support is needed to secure utility financing for R&D, demonstrations, and commercial projects.

- **Need to Overcome Negative Perception of Early Projects.** Several renewables continue to suffer the aftereffects of their early deployment in the 1970s and 1980s. Since that time, major technical advances and a more experienced and tested industrial base have been realized. Moreover, a strong education program would help to overcome any lingering misconceptions.

- **Strong Foreign Competition.** Tied-aid and strong support by foreign governments for their firms make it difficult for U.S. industry to compete in the international marketplace. Coordinating U.S. government export assistance programs will assist in developing competitive bids.

These findings demonstrate the need for continued federal, state, and local government support to advance solar electric technologies into the power sector marketplace, develop the necessary environment to secure project financing on competitive terms, and address utility and other end-user needs.

SOLAR 2000 represents a new emphasis for DOE, which has traditionally focused its support on technology R&D; leaving technology commercialization to industry. While the DOE Photovoltaics, Solar Thermal and Biomass Power Divisions will continue their efforts in basic and applied R&D, the Office of Solar Energy Conversion, which oversees these divisions, will take the DOE lead in working with public and private sector participants to ready the marketplace for these technologies. In this capacity, OSEC will work in partnership with industry to ensure that these U.S.-based technologies are viable competitors for the domestic and international marketplace. The SOLAR 2000 program will build upon and leverage private sector successes as needed. SOLAR 2000 supports the view that the success of the U.S. solar industry depends on the private sector's ability to compete head-on with global competition.

III. TECHNOLOGY DEVELOPMENT AND VALIDATION

Technology development and validation efforts will focus on proof-of-concept activities relevant to emerging solar electric technologies and their performance validation. By working with industry to advance technologies through collaborative research, development and demonstration, OSEC will promote more reliable, durable, and cost-competitive solar electric systems in the marketplace. This component includes synchronizing the RD&D efforts with the needs of users, expanding the availability of resource data, and improving system performance.

Table III depicts the principal technology development activities in the PV, solar thermal, and biomass electric areas to be pursued over the next few years by DOE in collaboration with industry, utilities, regulators, and others. These activities fall into four major elements:

- **Research and Development** to improve performance of PV materials, cells and devices; basic and applied research to enhance the efficiency of solar thermal collection and conversion devices and continued development of improved conversion techniques and generation subsystems; and thermochemical conversion and system development for biomass electric technologies.

- **Manufacturing and Technology Development** to improve manufacturing processes and reduce costs for PV modules, solar thermal collector/ conversion subsystems, and biomass systems. This effort is conducted in close cooperation with industry to include component, module, subsystem and balance of system activities. PV-MaT is central to this effort in the photovoltaics area (see sidebar). Similar activities in solar thermal are being achieved through the production of units for field tests and support of a manufacturing facility for dish/Stirling systems.

- **Systems Development** to assess the performance and reliability of PV, solar thermal, and biomass electric systems today and recommend mechanisms for system enhancement in both near- and long-term market applications domestically and overseas. A major emphasis of this element is joint R&D collaboration between industry and

PHOTOVOLTAIC MANUFACTURING TECHNOLOGY (PV-MaT) INITIATIVE

Through joint government/industry efforts, U.S. industrial achievements in R&D that promise significant cost reductions, enhanced efficiencies, and higher system reliability are now being transferred to commercial products. An excellent example of this cooperation is the DOE-industry PVMaT Initiative, which employs a two-pronged path to achieve near-term manufacturing cost reductions for PV modules. Through PV-MaT, industry and government work together to transfer PV technologies: (1) from R&D into manufacturing, and (2) to expand the production of current commercial technologies based upon the existing state-of-the-art technology. The initiative is carried out in two phases: problem identification (about 3 months) and problem solution (5 years). Twenty-two companies were awarded contracts under Phase 1, which has now been completed. Phase 2 awards will be made in early 1992, and six companies are expected to be recipients. PV-MaT represents an innovative approach for enhancing industry's manufacturing capabilities and accelerating market entry.

Table III - Summary of OSEC Technology Development and Validation Activities

TECHNOLOGY / ACTIVITY	PHOTOVOLTAICS	SOLAR THERMAL	BIOMASS
Research & Development	• Strengthen interaction/funding by the DOE Office of Energy Research to enhance basic research activities. • Initiate capital equipment improvement program to develop/maintain state-of-the-art processing and measurement capabilities. • Augment flat-plate and concentrator module development program to obtain 30-year module lifetimes. • Joint govt./industry programs to transfer high efficiency III-V based multi-junction devices/modules and enhance reproducibility and scale-up.	• Support component and subsystem R&D with labs, universities, industry to improve power collection/conversion techniques. • Support industry R&D to realize low-cost durable multiple polymer films for stretched membrane heliostats and dishes. • Augment industry efforts to validate collection system designs through prototype tests of dish/heliostats. • Increase joint activities to perform on-sun test of advanced receivers and 25 kWe free-piston and kinematic Stirling engines.	• Develop techniques to prevent ash deposition and improve particulate removal to extend boiler/turbine life and efficiency. • Conduct biomass combustion dynamics assessments and address gasification from herbaceous feedstocks and the environment issues. • Support joint-ventures to develop 100 tons/day biomass gasifier & incorporate hot gas cleanup subsystem.
Manufacturing Technology Development	• Enhance PV-MaT to accelerate commercial thin-film/concentrator technologies, and accommodate new industrial entrants. • Improve BOS component performance/manufacturability. • Increase industry cooperation to evaluate/qualify commercial modules for utility-scale systems. • Augment industry supporting activities to improve module encapsulation materials for 30-year module life.	• Enhance industry collaboration to achieve lower-cost,durable, high-performance solar thermal systems. • Initiate central receiver heliostat manufacturing initiative to assist industry in commercializing solar collection systems through deploying commercial scale heliostats. • Augment industry efforts to mass produce 5 kWe dish/Stirling modules and support multiple 25 kWe dish/Stirling systems for utility use.	• Initiate efforts to develop a commercial hot-gas cleanup system. • Design improved biomass feedstock handling techniques and storage systems. • Encourage establishment of industrial consortia to enhance capacity of industry to bring products to market.
Systems Development	• Enhance PV/building integration for DSM and other uses. • Develop PV/hybrid system concepts and market applications. • Continue support for PVUSA. • Augment activities for advanced power conditioning and control systems from small to large-scale applications. • Validate performance of multiple multi-MW utility systems.	• Support tech transfer to achieve utility market penetration. • Assist industry to achieve 50% reduction in the O&M cost of commercial parabolic trough systems. • Continue with industry to support 5 kWe dish/Stirling systems. • Begin efforts to realize large-scale solar thermal central receiver and parabolic trough system deployment in the Western U.S.	• Conduct analysis to evaluate gasifier types/sizes, and future turbine options. • Complete biomass resource assessments and analyze environmental impact of biomass power systems. • Evaluate fast pyrolysis fuels for gas turbine applications. • Initiate efforts to explore large-scale (50-200 MW) biomass projects supported by necessary biomass feedstock plantation.
Resource Validation	• Compile updated solar radiation information. • Assess availability, quality, and accessibility of international resource data, needed for U.S. foreign competitiveness.	• Expand existing solar radiation network sites. • Support formulation of first 30-year solar resource database for U.S.	• Biomass feedstock assessment and characterization. • Regional resource assessment.

utilities to improve technologies, enhance user experience, and increase industry capabilities to service utility needs. In addition, OSEC will continue to work with the industry, users, and the DOE Office of Energy Management to improve storage technologies. Moreover, OSEC will continue to support the Photovoltaics for Utility Scale Applications (PVUSA) project to demonstrate the viability of emerging commercial PV technologies for utility applications. The PVUSA project provides a model for government/industry/utility R&D cooperation.

- **Resource Validation** to develop scientific understanding and quantitative assessment of the spatial, temporal and spectral characteristics of solar radiation resources. This is important for the design of solar electric technologies and performance predictions at different locations. In addition, efforts will be undertaken to build multi-regional domestic and international resource databases.

Volume II, Appendix I provides more detailed information on planned OSEC activities in the technology development and validation area.

IV. MARKET CONDITIONING

Market conditioning involves working with potential utilities and other technology customers -- both directly, as well as through key stakeholders such as state regulatory commissioners, policymakers, federal and state government agencies, public interest groups, U.S. industry and its trade associations (Solar Energy Industries Association) -- to mitigate market barriers to solar electric technologies. The premise of the market conditioning activity is that energy planning in the U.S. and overseas relies on analytic tools and regulatory/policy measures that favor traditional fossil-based (coal and oil) and large-scale hydro technologies. Environmental pressures, combined with a variety of other health, safety, fuel availability, and plant cost overrun concerns, are necessitating that the former ways of doing business be reevaluated to encourage more equitable consideration of advanced energy technologies such as PV, solar thermal and biomass power.

Among the OSEC activities planned, two substantive efforts will be pursued in the market conditioning area: **Decision Analysis and Standards Development** and a **Communications and Technology Transfer.**

DECISION ANALYSIS AND STANDARDS DEVELOPMENT

> *"The Rules of the Game for the next twenty years will be written in the next few years."*
>
> *Merwin Brown, Pacific Gas and Electric Company*

To properly evaluate solar electric technologies, a different set of project evaluation tools may be needed. The basis for this difference stems from the unique operational characteristics of these technologies, particularly solar thermal and photovoltaics. First, they have a higher upfront capital cost per unit than conventional options, but a much lower operating cost as they use a free fuel source (see Figure 10). Thus, PV and solar thermal are not subject to fuel price increases and escalation rates of fossil-based options. Second, they are modular in nature, and thus can be brought on-line in small increments by directly meeting customer needs, while reducing construction costs and lead times, as well as regulatory hurdles. Lastly, the technologies do not produce harmful emissions, and thus provide a solution for decisionmakers seeking ways to meet power requirements in an environmentally sound manner. Capturing these benefits will require innovative financing approaches to mitigate front-end costs.

Planning and Assessment Methods

OSEC will support value-based analyses for solar electric technologies, examine utility costing methodologies and resource bidding procedures, assemble and incorporate into planning tools solar technology cost data, and assess opportunities for solar electric technologies in demand-side management applications for several end-use sectors. OSEC will also examine integrated resource planning (IRP) methods to find ways of incorporating distributed grid-connected and

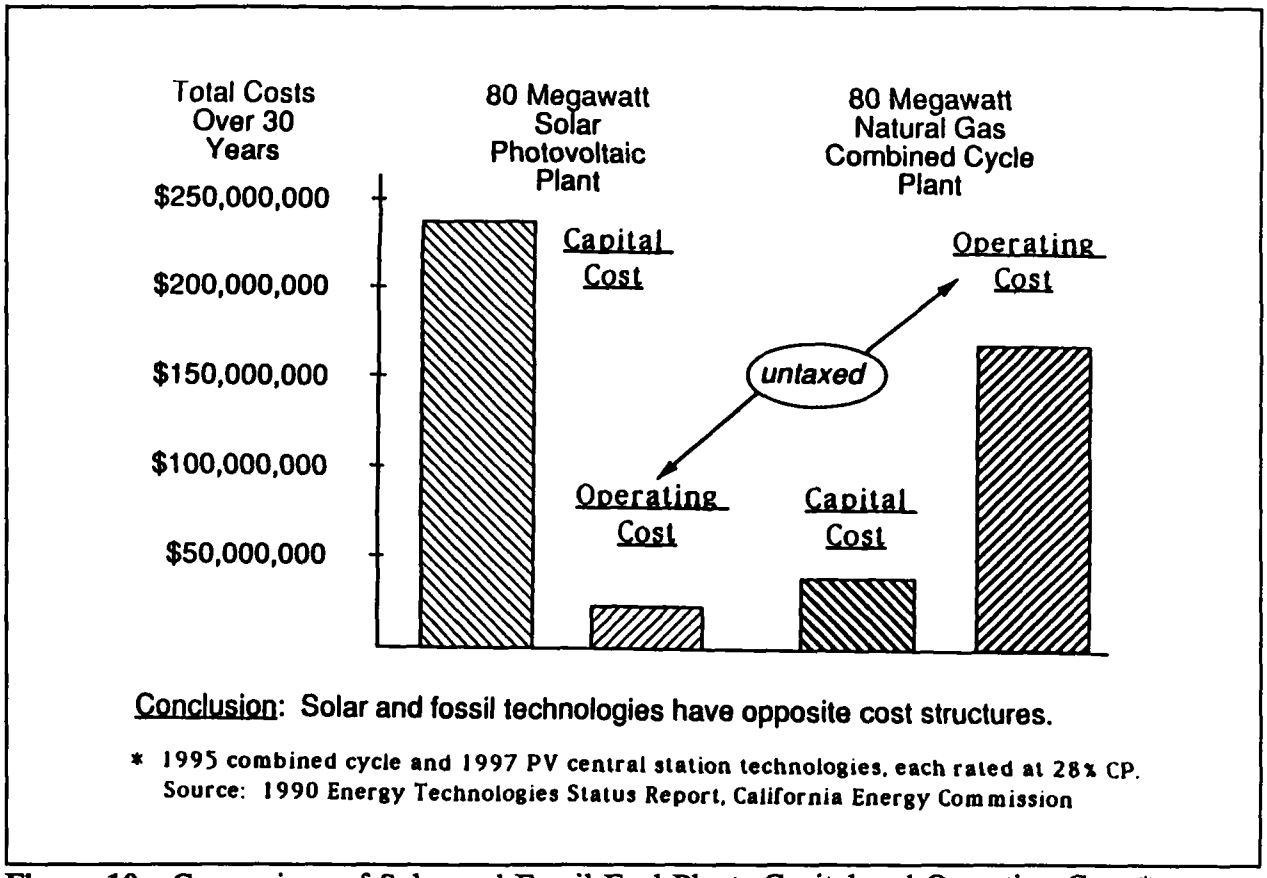


Figure 10 - Comparison of Solar and Fossil-Fuel Plants Capital and Operating Costs*

off-grid systems into the resource planning process. A number of activities are already underway:

- **Technology Characterizations.** OSEC is building an internally consistent set of technology performance and cost databases to compare solar electric to conventional technology options under a number of different scenarios. The information will be used for technology evaluations and national planning activities. This data base will be updated as new information is obtained.

- **Regulatory, Rate and Value Analyses.** OSEC will assist in identifying and removing regulatory impediments and rate making imperfections that limit the market for solar electric technologies. Efforts include working with public utility commissions to modify regulations affecting technology choice; encouraging the use of risk-adjusted discount rates in technology assessments; evaluating the impact of federal and state tax structures on technology competitiveness; and developing methods for assessing the value of solar electric technologies for utility applications such as demand-side management. It will also involve creating innovative approaches through the regulatory process to establish permissible boundaries for utility solar demonstration projects that would allow for full cost-recovery. This "safe harbor" approach has been used effectively in the conservation area.

- **Environmental Impacts Analysis.** OSEC is developing a coherent strategy of how to best represent solar electric technologies in light of the Clean Air Act Amendments (CAAA) and other initiatives. In particular, OSEC is supporting efforts to assist regulators and utilities to experiment with innovative pricing policies that would allow consumers to have a direct role in resource acquisitions made on their behalf ("green pricing").

- **Transmission Issues Evaluation.** OSEC is preparing an action plan for evaluating and resolving transmission issues affecting solar electric technologies. Transmission access is an especially important topic because solar electric technologies are capable of being located at load centers or distributed throughout the grid.

- **Manufacturing Issues Analysis.** As a follow-up to the PV-MaT initiative, OSEC is evaluating the conditions necessary for U.S. industry to scale-up manufacturing facilities to meet future market demand. This issue is central not only for PV, but also for dish Stirling and other technologies which depend on economies of scale in production to reduce cost.

- **Dedicated Fuel Supply System Assessment (DFSS).** OSEC will evaluate issues related to the establishment of dedicated biomass fuel supply systems in the U.S. as mechanism for ensuring long term, reliable fuel resources for large-scale biomass electric facilities.

- **Environmental Safety and Health.** OSEC will prepare an action plan to ensure that solar electric technologies meet all environmental health and safety standards through its complete R&D, manufacturing, use, and waste disposal cycle. It builds upon work conducted by Brookhaven National Laboratories, the Secretary of Energy Tiger Team, the National Environmental Policy Act (NEPA), and a number of states.

- **International Competitiveness Analysis.** A number of countries, in particular Japan and Europe, sponsor well-funded PV programs, and monitor U.S. PV efforts in these areas. OSEC will monitor international activities and propose strategic actions for strengthening U.S. competitiveness.

The results of these analytical efforts will be put into practice to accelerate the rate of adoption of solar electric technologies. Undoubtedly, new ideas and issues will emerge as SOLAR 2000 progresses, and OSEC will continue to pursue new opportunities as they arise.

Codes and Standards

Codes and standards provide the customer with information on expected technology capabilities and performance. In this light, OSEC is supporting the development and adoption of relevant codes and standards by local, state, national and international groups. Cooperative efforts are ongoing or planned with several groups including the Institute of Electrical and Electronics Engineers (IEEE) Standards Coordinating Committee, the PV-Underwriters Laboratories (UL) Industrial Advisory Group (for revising UL Standard 1703), the Power Engineering Society, the Electric Power Research Institute, and the National Fire Protection Association. OSEC has also taken the lead in developing module qualification tests and standards and in working with

PVUSA to develop systems testing and monitoring procedures. These activities are critically important to support the technology transfer effort.

COMMUNICATIONS AND TECHNOLOGY TRANSFER

A recent survey by the University of Delaware reveals that most state regulatory commissions and utilities appear to be unaware of the value of PV technologies; that is, the benefits of these technologies that are not currently accounted for by the marketplace.[20] OSEC will support an aggressive and sustained communications effort to ensure that the advantages of solar electric technologies are adequately disseminated in the marketplace. OSEC will play a facilitator role in these efforts by supporting activities led by trade associations and other stakeholders associated with the development and utilization of solar electric technologies both at home and abroad. The communications and technology transfer effort will:

- Increase market awareness of technology benefits and promote the use of solar electric technologies for present, cost-effective applications;
- Build a consensus for technology development and utilization in all applicable sectors worldwide;
- Transfer results and decision analysis tools developed in the Decision-Analysis and Standards Development effort to key decision-makers; and
- Encourage U.S. joint venture projects both domestically and internationally.

A number of activities will be undertaken to support these objectives, including public communications, conference sessions, regional symposia, and targeted workshops.

Public Communications. OSEC is supporting an ongoing effort to disseminate information on solar electric technologies to the general public. Communication activities will focus on key states (and countries) and will work with consumer groups and decision-makers requiring up-to-date information on solar electric costs and benefits. In the biomass area specifically, consumer groups will be targeted to address concerns with regard to emissions and forest management issues related to woody biomass harvesting.

Conference Sessions. OSEC will support technology workshops and sessions at established conferences and meetings which attract target customer and stakeholder audiences. There is evidence that these sessions can have an important impact on market conditioning. For example, SEIA-led efforts at the last two meetings of the National Association of Regulatory Utility Commissioners (NARUC) have significantly enhanced state regulatory awareness of renewable energy technologies and have resulted in project opportunities between NARUC, industry and others. OSEC, in collaboration with USAID and other government agencies, will also support conference sessions aimed at developing country officials that highlight the benefits of specific, relevant applications for U.S. solar electric technologies.

Regional Symposia. Regional solar electric technology symposia for specific states will be conducted in partnership with industry trade associations, state energy offices, and other appropriate organizations. These symposia will provide forums in which the interrelationship of technology, regulatory, and energy policy issues can be examined on a regional basis. The target audiences will consist of a cross-section of participants from all of the major stakeholder groups. OSEC, together with its partners, will use these opportunities to communicate technology benefits, build consensus among stakeholders, support joint venture projects and assist in the development and transfer of decision methodologies for solar electric technologies.

Targeted Workshops will be most effective in addressing the specific needs and concerns of key stakeholders. Successful examples of such targeted efforts include the SEIA/National Association of State Energy Officials (NASEO) dialogues; SEIA/NARUC discussions; Sandia National Laboratories (SNL) Central Receiver Workshops; and the EPRI high-value photovoltaic applications workshops. Specific workshops are planned in which OSEC, together with other key groups, will address decision-making at the state regulatory level. For example:

- Workshops will be held to promote utility costing, resource bidding, and regulatory decisionmaking approaches which account for the full value of solar electric technologies (such as environmental benefits and insurance against future fuel price escalation). These workshops will help mitigate the decreasing ability of PURPA regulations to level the playing field for renewable energy technologies.

- Workshops will also be targeted toward decision-makers in the federal Power Marketing Authorities (PMAs) which comprise a critical segment of the power market under DOE jurisdiction. PMAs not only play an important role in wheeling power, but can also generate it, as is the case with Bonneville Power Authority (BPA). In either instance, numerous applications exist for solar electric technologies in both transmission line support and in generation.

- Other workshops will be targeted toward decision-makers in selected developing countries to address ways in which solar electric technologies can be included in rural electrification plans and other relevant sector applications (i.e., agriculture, industry, household). Each workshop will be highly specific in terms of applications and participation. OSEC will work closely with the newly formed Asia Technical Alternative Energy (ASTAE) Unit at the World Bank to promote more widespread use of PV, solar thermal and biomass power in appropriate end uses.

V. JOINT VENTURE PROJECTS

In an effort to reduce potential risks associated with solar electric power plants, OSEC will participate in joint venture projects with utilities and other customers to prove that solar electric technologies can fully meet end-user cost, performance and reliability requirements for value-added applications. Such joint ventures are especially effective in leveraging private-sector resources to absorb the high front-end costs and reduce risks of demonstration for technologies with little or no track record in commercial applications. These ventures will bring stakeholders together to achieve broad commercialization activities which would not otherwise occur -- or not occur in time to ready solar electric technologies for the expected surge in demand for power at the end of the decade. In addition to project participation, OSEC will continue to provide technical assistance to identify, evaluate, design, implement, and leverage funding for innovative projects.

One of the principal obstacles to developing commercial solar electric projects is risk. New technologies and new applications that have not been commercially demonstrated and adopted on a wide-scale basis are perceived by regulators, investors, utilities and other end-users as risky ventures. This perception has, in part, been created by the experience of the late 1970s and early 1980s when another capital-intensive technology -- nuclear -- experienced large cost overruns, excess capacity, high fuel costs and public opposition.

A number of risks require mitigation:

- **Technology risk** -- the possibility that the technology will not perform as specified.
- **Construction risk** -- the possibility of cost overruns and/or an inability to meet schedules.
- **Operating risk** -- the possibility of a breakdown, and the unavailability of power when needed.
- **Regulatory and tax risk** -- the possibility, in the utility market, of having investments disallowed, tax credits or accelerated depreciation expire, or other regulatory uncertainty.
- **Financial limitations** -- the high cost of financing due to perceptions of the above risks. These costs diminish the competitiveness of some OSEC technologies.

Solar electric technologies figure positively in a number of these areas. For example, their modular nature reduces construction risk and regulatory hurdles. Operating risks are minimal for technologies which require no fuel and little maintenance. Financial risks in today's way of doing business are higher for capital-intensive solar electric technologies. Yet, if their benefits were more adequately accounted for to consider favorable fuel and environmental benefits, these risks could be less than conventional options (see Section IV, Market Conditioning).

Where unacceptably high risks continue to exist, OSEC will work closely with key stakeholders to better demonstrate technologies and new applications, stabilize the regulatory environment, and reduce hurdle rates. Joint ventures, where all participants have a stake in the investment, are the best mechanism for mitigating these risks.

OSEC will form joint ventures with utilities, the solar electric industry, state agencies, and other federal government agencies (including PMAs) for domestic project development. International joint ventures will include partnerships with U.S. government agencies, multilateral donors, and organizations in the target countries.

Joint ventures can take many forms. OSEC will work with **Utilities and Industry** as a partner to support pre-competitive R&D and pilot projects. In **State Government** projects, the joint ventures are applications oriented. Stakeholders will be aggregated at the state level and cost-sharing will be performed with state energy programs. In **Federal Government** projects, collaborative activity will revolve around the needs of specific government agencies. These are wholly commercial efforts to move the government squarely into the market for solar electric technologies. In **International** projects the emphasis is on opening foreign markets to U.S. solar electric technologies by establishing the financial infrastructure required to finance these systems. As these programs demonstrate, OSEC has the flexibility to participate with other stakeholders in various collaborative arrangements. Complementing these joint ventures, OSEC will continue to lend technical assistance for specific PV and solar thermal projects with important demonstration value both at home and abroad. As can be seen in Table IV, OSEC is a player in several joint venture projects.

Utility and Industry Joint Ventures

OSEC will work with existing projects, while encouraging the establishment of new cost-sharing ventures, in order to commercialize solar electric technologies. Such efforts include:

- **Utility PV Joint Venture.** A workshop organized by SEIA in December 1991 in Tucson, Arizona, represented the first step in convening utilities, regulators, and government decisionmakers to initiate development of a national photovoltaic strategy for utilities. This was a collaborative effort involving the Edison Electric Institute (EEI) and DOE, among others, with follow-on activities to include the American Public Power Association (APPA). This project is open to any stakeholder who wishes to participate, and the collaborative group is expected to expand over time. High value utility-related applications represent the initial target market. Economic and technical validation projects, developed in collaboration with other stakeholders, will be used to establish the commercial viability of utility PV applications with near-term cost-effectiveness. (Value analysis included in the market conditioning effort will be specifically designed to support this effort.) Participants are hopeful that this collaborative effort alone will achieve the deployment of 100-200 MW of PV by 2000.

TABLE IV - DISTRIBUTION OF JOINT-VENTURE PROJECTS

	PHOTOVOLTAICS	SOLAR THERMAL	BIOMASS
UTILITIES AND INDUSTRY	• Utility PV Joint Venture Technical Assistance • Niagara Mohawk • KC Electric • P.S. of Colorado	• Solar Two Central Receiver • Dish/Stirling Technical Assistance • Plains Electric	• Wood-Fired Gas Turbine • Biomass Repowering Project • Biomass Power Plantation
STATE GOVERNMENT	• PV Buildings		
FEDERAL GOVERNMENT	• Department of Defense • PMAs (BPA/WAPA) - TBD Technical assistance • Other agencies	• PMAs (BPA/WAPA) - TBD	• PMAs (BPA/WAPA) - TBD
INTERNATIONAL	• Financing Energy Services for Small-Scale Energy Users (FINESSE) • Mexico Rural Electrification • Virgin Islands	• FINESSE	• FINESSE
FUTURE INITIATIVES	TO BE DETERMINED		

- **Solar Two Central Receiver Project.** The Solar Two project is a joint-venture effort between OSEC and utility sector. This collaborative effort is being led in partnership by the U.S. Department of Energy and the Southern California Edison (SCE) company with technical support from the Sandia National Laboratories. SCE, responsible for securing commitments for the 50% cost-share for the utility sector, has successfully obtained

commitments from several utilities (see sidebar). Solar Two project consortium will convert the Solar One Pilot Plant in Barstow, California, to an experimental 10 MW solar power tower utilizing a nitrate-salt heat-transfer and thermal storage medium. The resulting Solar Two project will provide information and an expanded manufacturing base needed for scaling up the plant to a 100 MW unit scheduled for completion in 1997. Scale-up is designed to coincide with projections for future capacity expansion in the Southwest region at the turn of the century. Several industry and utility organizations have already agreed to be on a Solar Two Project Steering Committee and are committing private funds for this project in coming years. Solar Two project efforts will reduce technical, construction and operational risks and address financial limitations to a utility-scale 100 MW central receiver project.

SOLAR TWO STEERING COMMITTEE

- Southern California Edison
- Los Angeles Department of Water and Power
- Sacramento Municipal Utility District
- Idaho Power
- Pacific Gas & Electric
- PacifiCorp
- Arizona Public Service and Salt River Project (shared seat)
- California Energy Commission
- Electric Power Research Institute (through tailored contribution)
- U.S. Department of Energy
- Sandia National Laboratories (Technical Assistance)

- **Dish/Stirling Joint Venture Project.** OSEC is facilitating the development of a vertically integrated consortium for the commercialization of economically competitive dish/Stirling systems and is supplying cost-shared funding. Cummins Power Generation, which is also cost sharing this effort, has been awarded a contract to continue key technology development. Three generations of 5 kWe dish/Stirling systems will be installed and field tested under this joint venture. Phase 1 will demonstrate water pumping and village power applications. Phase 2 will validate the design of water pumping and village electrification modules. Phase 3 will deploy a total of ten "manufacturing validation" modules. Georgia Power, AT&T (Phoenix), Hawaii Electric, and PG&E have agreed to host tests and to provide all of the installation and test support costs. In addition, efforts are underway to create a similar joint-venture project for the 25 kWe dish/Stirling system.

- **Biomass Direct Wood-Fired Gas Turbine Project.** Subcontract negotiations are underway with Power Generating Inc. (PGI) for a 3-year, $5 million effort to commercialize the direct wood-fired turbine concept. The cost will be shared between PGI, DOE Morgantown Energy Technology Center, and OSEC. The project, begun in the fall of 1991, meets scale-up needs in predominantly niche markets.

- **Biomass Repowering Project.** OSEC plans include support of the conversion of coal-fired steam to biomass fuel plant. Plants under consideration are those units that can be converted from coal to fluidized bed combustion, whole tree burner, hydro-cooled grates or other biomass energy technologies. Such conversions will allow comparisons between the technologies and provide demonstrations of biomass energy potential, credibility and government support. The externalities associated with the projects will also be assessed.

- **Biomass Power Plantation (BPP) Project.** OSEC is building a collaborative effort to establish a joint venture with a major utility for a biomass power plantation to supply a 10-60 MW grid-connected biomass power system. The project will be located at a site where sufficient wood residues are available to supply the feedstock needs of the project in the early years of its operation. OSEC anticipates that it will take approximately 5 to 6 years to fully establish the energy crop plantation, the length of time required for harvesting short rotation woody crops. OSEC will address harvesting, handling and storage issues while the DOE Biofuels System Division, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL) and U.S. Department of Agriculture (USDA) will address energy crop production issues.

State Government Initiative

The **PV Buildings Initiative** will leverage state, utility and industry funds to support product development and replicable demonstrations of PV for demand-side management applications in residential, commercial, and institutional buildings. In this effort, OSEC will work closely with the ten DOE support offices, state energy offices, and other stakeholders. The DOE State Energy Program and the ten support offices have traditionally assisted in efforts at the state level to improve energy efficiency and enhance renewable energy utilization. The result of the PV Buildings Initiative will be new PV products such as walls and roofs that can be incorporated into the design and construction of new and existing buildings.

Federal Government Initiatives

OSEC is undertaking major initiatives to spur government procurement of solar electric technologies. The government market, both federal and state, is vast and the opportunity to develop substantial solar electric projects is promising. OSEC will initially develop joint venture projects with the Department of Defense (DOD) and the PMAs.

- **Department of Defense PV Joint Venture.** The single largest energy consumer in the United States, the DOD, presents abundant opportunities for PV applications. The DOD PV project is designed to achieve the deployment of 100 MW of PV power in the military by 1996. Required in conjunction with the FY '91 Military Appropriations legislation, the DOD PV Review Committee is implementing this project with OSEC support. Likely projects include utility-interactive applications in the Southwest, and off-grid applications worldwide. An island repowering project off the Southern California coast is a near-term opportunity.

- **Power Marketing Authority Joint Venture.** This project will engage the Power Marketing Authorities in OSEC's solar electric program. Besides wheeling power, with its large potential for PV line support and DSM applications, some PMAs engage in power generation, providing important opportunities to demonstrate solar electric applications. To date, two PMAs have come forward -- Bonneville Power Administration and Western Area Power Administration (WAPA) -- and they will be receiving continued OSEC support.

International Joint Venture Project Development

OSEC is seeking to open the vast potential markets in the developing world to U.S. solar electric technologies. This requires the establishment of mechanisms for financing small-scale projects for rural electrification applications, and lending technical assistance to support aggressive developing country efforts to utilize these technologies in appropriate applications. The approach is to take the path of least resistance, working with countries that are postured to facilitate, rather than obstruct, the deployment of solar electric technologies, and where U.S. suppliers have a competitive advantage. OSEC has several projects in the international area, which are supplemented by numerous, smaller scale Design Assistance Center (DAC) projects throughout the world:

- **Financing Energy Services for Small-Scale Energy Users (FINESSE).** Project FINESSE was initiated at the 1988 Energy Research Donors Meeting to explore ways to accelerate the adoption of alternative energy technologies -- energy efficiency and renewable energy technologies -- in meeting the growing energy needs of the developing world. Key project sponsors include the U.S. government (Department of Energy, Environmental Protection Agency, and the Agency for International Development), the Netherlands Ministry of Foreign Affairs, and the World Bank. Phase I of the project involved a number of activities including the conduct of country market studies, development of business plans for promoting alternative energy products and services, and an assessment of energy efficiency manufacturing alternatives for the Southeast Asian region. These initiatives culminated in a landmark workshop in October 1991 held in Kuala Lumpur, Malaysia, which assembled lenders, borrowers, intermediaries, equipment suppliers, and end-users to develop replicable models for incorporating alternatives within host country energy planning, and in so doing, to provide positive impacts on energy supply, industrial growth, employment, and revenues.

  > *"...it is very clear that in the fields of renewable energy alternatives and energy conservation, investment opportunities do exist that meet the test of financial and economic viability."*
  >
  > *Daniel Ritchie, Director, Asia Technical Department, World Bank*

  Three major results occurred from the workshop. First, host country decisionmakers took an aggressive lead in planning their energy futures and demonstrated strong support for incorporating alternative energy technologies as a key component of their planning processes. Philippines President Corazon Aquino, for example, made a public announcement that her government supported and would adopt the FINESSE Program. Second, over $800 million in alternative energy projects were identified for the four participating countries of Indonesia, Malaysia, Philippines, and Thailand. Lastly, the World Bank announced that it was committed to bringing alternative energy technologies into mainstream lending operations. Since the Workshop, the World Bank has followed up on this proclamation by establishing the Asia Technical Alternative Energy Unit, and securing donor commitments of over $2 million in 1992 to support office activities. These will

include training World Bank and host country staff on the status, benefits, and applications for alternatives; incorporating the pipeline of projects identified at the workshop into upcoming Bank projects; conducting project preparation and investment analyses; and replicating FINESSE throughout Asia and ultimately to other regions addressed by the Bank.

In summary, FINESSE represents a success story for energy efficiency and renewables that was initiated by the U.S. government, and will ultimately assist both U.S. industry and the developing world.

- **Latin American Initiative.** OSEC is working with industry, host country governments, and other U.S. government organizations to promote U.S. solar electric technologies for appropriate end uses in Latin American, particularly Mexico and Central America.

  -- **Mexico Rural Electrification Project.** DOE, together with USAID, is providing technical support to Mexico in the development and implementation of a rural electrification program emphasizing renewable energy. The Mexican National Solidarity Program, known as PRONASOL, funds rural electrification projects through private contractors and the national electric utility. Renewable technologies being utilized in this effort include photovoltaics, wind-electric turbines, small hydro, solar thermal, and biomass. This program is the first attempt to systematically include numerous renewable energy technologies in a national rural electrification program. The lessons learned from this program, and perceptions of its performance, are expected to have a strong impact on the electrification programs of other countries.

  U.S. support includes technical assistance and training in project development, decision analysis, program evaluation, comparison of grid extension with distributed systems, and joint development of pilot projects. Program financing through the Export/Import Bank (EXIMBANK) is also under arrangement. OSEC is prepared to offer assistance and training in technology evaluation and selection, system design, development of component and system technical standards; resource assessment; program design; development of end-user financing mechanisms; and economic analysis. This activity is also being supported by the DOE Office of Technical Assistance and the Office of Renewable Energy Conversion.

  -- **Central America/Caribbean.** DOE plans to expand its efforts in Mexico to a number of other Central American and Caribbean countries, to potentially include Guatemala, Costa Rica, and the Dominican Republic. Efforts will include assistance in identifying and developing solar electric projects that make sense on an economic, technical, environmental and social basis, as well as to assist in structuring the institutional framework for acquiring, installing, operating and maintaining these systems.

In addition, OSEC will continue to work with the Committee on Renewable Energy Commerce and Trade (CORECT) in supporting U.S. industry's international project development efforts. Specifically, OSEC will consider supporting solar electric technology projects in conjunction with the International Fund for Renewables and Energy Efficiency (IFREE) -- the multi-agency prefeasibility study fund established by US/ECRE and funded by the U.S. government.

Technical Assistance

OSEC will lend technical assistance to facilitate the deployment of important demonstration projects, usually smaller in scale than those discussed so far, and which cut across various end-user groups including utilities and government. Much of this technical assistance will be rendered by the PV and Solar Thermal (ST) Design Assistance Centers at Sandia National Laboratories.

- **Photovoltaics Design Assistance Center (PV DAC) Activity.** Sandia has an ongoing program in the design assistance areas that has involved over 100 projects in the U.S, Pacific Rim, Latin America/Caribbean and Africa. Some current projects include lending technical assistance to Niagara Mohawk for a PV demand-side management project in Albany, NY, and assistance in PV projects in a number of national forests in cooperation with the Department of Interior. The PV DAC is also providing assistance to the Virgin Islands Energy Office following the devastation of Hurricane Hugo, where efforts focus on evaluating PV for water pumping, participating in the Mexico rural electrification project, supporting Project FINESSE, and spurring solar technology adoption in Guatemala and Dominican Republic. PV DAC has also worked with KC Electric in eastern Colorado on the installation of a PV-powered water pumping system as a customer option that is more cost-competitive than line extension. In addition, PV DAC supports NREL's efforts in providing technical assistance to Public Service of Colorado in evaluating the use of a PV-hybrid system for supplying power to the town of White Pine, Colorado.

- **Solar Thermal Design Assistance Center (ST DAC) Activity.** The ST DAC is a member of the Cummins Generation Company's 5 kW dish/Stirling commercialization team providing testing and other technical support. ST DAC is also assisting the Cummins team in structuring a directed R&D initiative for solar thermal applications to identify solar electric technologies that are near commercialization. The plan is to co-fund an effort to complete development of commercial products. ST DAC is also working with the Plains Electric Cooperative in Albuquerque, NM, to study the possibility of using a solar thermal system at one of the existing Plains' facilities.

Future Initiatives

OSEC will maintain a dynamic program designed to respond to new opportunities in the marketplace. Joint-venture proposals must meet the following criteria: (1) strong industry backing; (2) ability to mobilize/influence decision-makers; (3) ability to open up a large market; (4) offers significant value to the U.S.; (5) has a demonstrable need for OSEC support; and (6) brings co-funding support.

These OSEC collaborative programs, both domestically and internationally, will continue to support technology demonstration and market development efforts to bolster users' confidence in solar energy electric technologies and strengthen the industrial infrastructure for manufacturing these systems in the U.S. Together, these programs will facilitate the movement of solar electric technologies into the mainstream of worldwide energy technologies selection.

VI. MANAGEMENT PLAN

ORGANIZATION

The Office of Solar Energy Conversion, located within DOE's Office of Utility Technologies, is the lead office at DOE responsible for interfacing with and supporting key stakeholders in SOLAR 2000. In this capacity, OSEC will collaborate with organizations critical to the ultimate success of this strategy. Industry provides technical expertise, R&D funds, manpower, and facilities; expanded and improved manufacturing capabilities; and technically proven, cost-competitive products and services. Utilities, other users, and investors create the demand for solar electric technologies and bring the capital and support for technology demonstration and project implementation. Regulators and policy-makers help shape the regulatory and legislative playing field toward more equitable consideration of solar technologies and help facilitate market conditioning through large investment in solar electric technologies.

In addition to its facilitator role, OSEC brings R&D funding, technical expertise, market conditioning support, and funds for joint ventures. OSEC will draw on the technical expertise available at the National Renewable Energy Laboratory and Sandia National Laboratories in implementing SOLAR 2000. By building upon the individual strengths of each participant, OSEC can bring the weight and resources of the federal government to help ensure that SOLAR 2000 objectives are met in a cohesive and effective manner, making optimal use of limited resources.

OSEC RESOURCE SUMMARY

Table V summarizes the OSEC resources required to implement SOLAR 2000. These estimates are based upon the projected costs for achieving the technology development, market conditioning and joint-venture project development targets. In FY 1992 and FY 1993, major portions of the funding will be allocated toward technology development and validation. In subsequent years, increasing resources will be devoted to joint venture project development and market conditioning. Joint venture activities will require costs to be shared by all the stakeholders in a project. Resources allocated towards collaborative projects could increase depending on projects presented to OSEC in the future. OSEC is currently reviewing the resource requirements for technology development and validation for FY 1994 and beyond.

FY 1992-93 MAJOR MILESTONES

Table VI represents SOLAR 2000 major milestones for fiscal years 1992 and 1993.

TABLE V - PROPOSED OSEC RESOURCE REQUIREMENTS
(Millions of 1991 Dollars)

	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996
TECHNOLOGY DEVELOPMENT & VALIDATION					
- Photovoltaics	57.1	Currently Under Review for Reauthorization			
- Solar Thermal Electric	12.8				
- Biomass Power	3.2				
- Resource Validation	1.2				
MARKET CONDITIONING					
- Decision Analysis & Standards	0.2	0.4	0.4	0.4	0.4
- Communications & Technology Transfer	0.2	0.4	0.4	0.4	0.4
JOINT VENTURE PROJECTS					
Utility and Industry					
- Utility PV Initiative	1.0	4.5	9.0	10.5	12.5
- Solar Two Central Receiver	6.1	7.0	6.9	0.0	0.0
- Dish Stirling	1.8	2.3	1.3	0.5	0.5
- Biomass Direct Wood-Fired Gas Turbine Project	0.5	1.5	1.5	1.0	0.0
- Biomass Repowering Project	0.1	1.3	7.0	6.0	5.0
- Biomass Power Plantation Project	0.2	1.0	2.0	0.0	0.0
State Government					
- PV Buildings Initiatives	1.0	4.3	7.0	7.0	5.0
Other Federal Government Agency					
- Department of Defense PV Project - (Strategic Environmental Research Development Program (SERDP) Funds)	4.0	Resource requirements under consideration			
- Power Marketing Authority (BPA/WAPA)	Project under consideration				
International Projects					
- FINESSE	0.4	1.0	2.0	2.0	2.0
- Mexico PV Rural Electrification Project	0.5	0.5	0.3	0.2	0.1
New Joint Ventures	Resource requirements will depend on project submitted to OSEC				
Other Design Assistance Activities	0.5	0.5	0.5	0.5	0.5

TABLE VI - SOLAR 2000 MAJOR MILESTONES

FISCAL YEAR 1992	FISCAL YEAR 1993
TECHNOLOGY DEVELOPMENT & VALIDATION	
PHOTOVOLTAICS	
• Award six PVMaT company-specific process research (Phase 2A) contracts.	• Award 1 to 2 PVMaT generic research (Phase 3A) contracts and 1 to 2 additional company-specific process research (Phase 2B) contracts.
• Continue PVUSA by initiating three new-technology system validation experiments and organizing a utility substation (500 kW) demonstration.	• *Install three new-technology system validation experiments* and begin procurement of a utility substation validation system.
• Award up to 6 utility/industry cooperative contracts to fabricate and test advanced commercial amorphous silicon modules.	• Develop PV power processing hardware capability for diesel replacement and hybrid applications.
• Fabricate and test industry-produced advanced thin-film modules having 10% efficiency.	• Fabricate and test a 35% efficient commercial concentrator cell assembly.
SOLAR THERMAL	
• Prepare and implement an industry driven, market oriented five year research and development plan.	• Initiate collector manufacturability project to lower cost and improve performance.
• *Complete molten salt component* development.	• Document performance of new optical materials.
• Validate performance of dish-engine systems.	• Document performance and assess progress of reflux receivers.
• Initiate trough system operational and maintenance cost reduction program.	
BIOMASS	
• Initiate hot gas cleanup development	• Test and document hot gas cleanup system.
• Construction of 100 ton/day gasifier.	• Begin operation of 100 ton/day gasifier.
• Prepare and implement an industry driven, market oriented five year research and development plan.	
RESOURCE ASSESSMENT	
• Develop National Solar Radiation Database	• Conduct comprehensive *renewable energy resource* assessment
MARKET CONDITIONING	
• Develop comparative technology cost/performance database	• Implement accounting techniques
• Assess PV-distribution substation economics	• Evaluate risk adjusted discount rates for investments
• Develop innovative PUC/utility solar electric strategies	• Assess load matching potential for DSM applications
• Identify transmission issues	• Prepare Environmental Safety & Health action plan
• Collaborate with NARUC on Utility Applications Handbook and Barriers Assessment	• *Define benefit stream for distributed technologies*
	• PMA Workshop
	• SOLAR 2000 Review Meeting
	• Explore IRP opportunities in Arizona and other states
JOINT VENTURE PROJECTS	
• Initiate PV-Utilities Cooperative Venture to articulate value added markets.	• *Utilities Cooperative Venture implemented* in 5 or more states.
• Solar Two detailed design.	• Solar Two under construction.
• First solar/engine systems for remote applications operational.	• *Utility scale solar/engine system under development.*
• 5-7 PV-buildings applications designs underway.	• Best PV-building application designs being constructed.
• World Bank prepares $800M ASEAN FINESSE projects.	• *First world tenders released under Project FINESSE.*
• Initiate U.S.-Mexico cooperative program.	• Begin work on biomass electricity projects.
• Define 2-3 biomass/electricity ventures.	• Initiate dedicated biomass feedstock supply to power *project.*

VII. SOLAR 2000 OUTCOME

Through continued research and development and new commercialization initiatives, the collaborative SOLAR 2000 strategy represents a comprehensive, systematic approach for ensuring increased energy independence and a healthier environment for the nation -- at an affordable cost. The strategy draws its strength not only from its thorough analytical foundation, but also from its emphasis on extensive government/industry/customer cooperation to offer cost-effective alternative energy options to utilities and other customers. For its part, the DOE is in a position unique to public agencies to bring producers and end-users together in an effort to catalyze and expedite the further rapid commercialization of solar electric technologies. The approach selectively applies public resources toward addressing the shortcomings inherent in any emerging, high technology market.

OSEC expects SOLAR 2000 to lead to the increased commercial use of U.S. solar electric technologies by the power sector. By the year 2000, OSEC envisions that U.S. solar electric technologies could add more than 8,000 MW to meet the huge need for power worldwide.

- **1,400 MW of U.S.-made PV systems worldwide could be in use, with about 900 MW installed in the U.S. and 500 MW overseas** during 1991-2000 (Figure 11). About 100 MW of U.S. PV systems were installed worldwide during the 1980s.[21] The aggressive projected market growth assumes the following economic and market conditions: significant improvement in the cost and performance of PV systems; wider adoption of

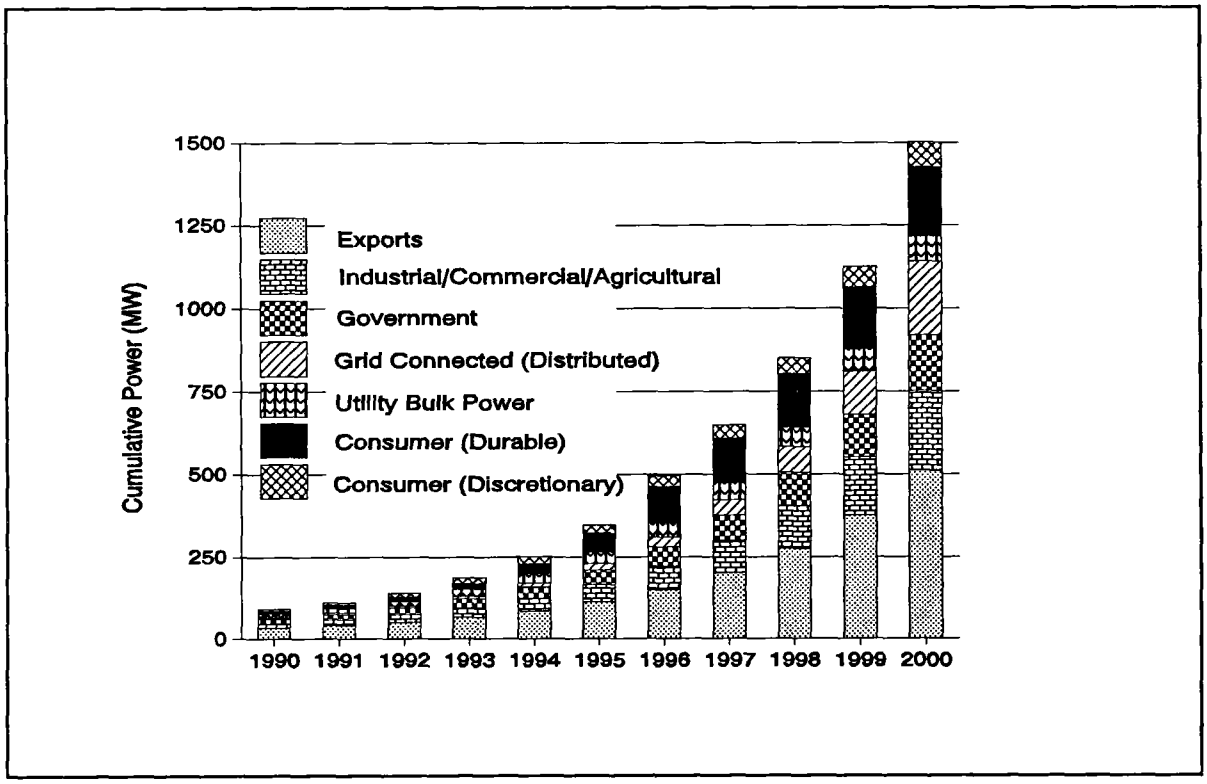


Figure 11 - PV Market Development Projections

integrated resource planning methods; greater regulatory pressure for significantly improved environmental quality; greater commitment by state and federal government agencies to PV utilization for cost-effective applications; and utility recognition of the benefits of PV as a distributed power source.[22] SOLAR 2000 expects the U.S. consumer, government, industrial/commercial/agricultural, and grid-connected distributed applications market to each account for approximately 15% of the cumulative market; the bulk power market share at 5%; and the export market share at 35%.[23] Electric utilities are expected to play a major role in the bulk power and distributed grid-connected markets. In addition, utilities are expected to serve the other market segments, particularly the industrial/commercial/ agricultural and the consumer durable market segments, which will provide increased use of PV in utility applications.[24]

- **Installation of 930 MW of U.S. solar thermal electric systems worldwide** with 440 MW in the U.S. and 490 MW overseas during 1991-2000 (Fig. 12). There is currently 355 MW of installed solar thermal electric systems in the United States, all of which has been developed, built, and operated by Luz International Ltd. In November 1991, Luz filed for reorganization, however it is expected that 80 MW of additional solar parabolic trough capacity will be built in the upcoming years, raising the total installed capacity of such

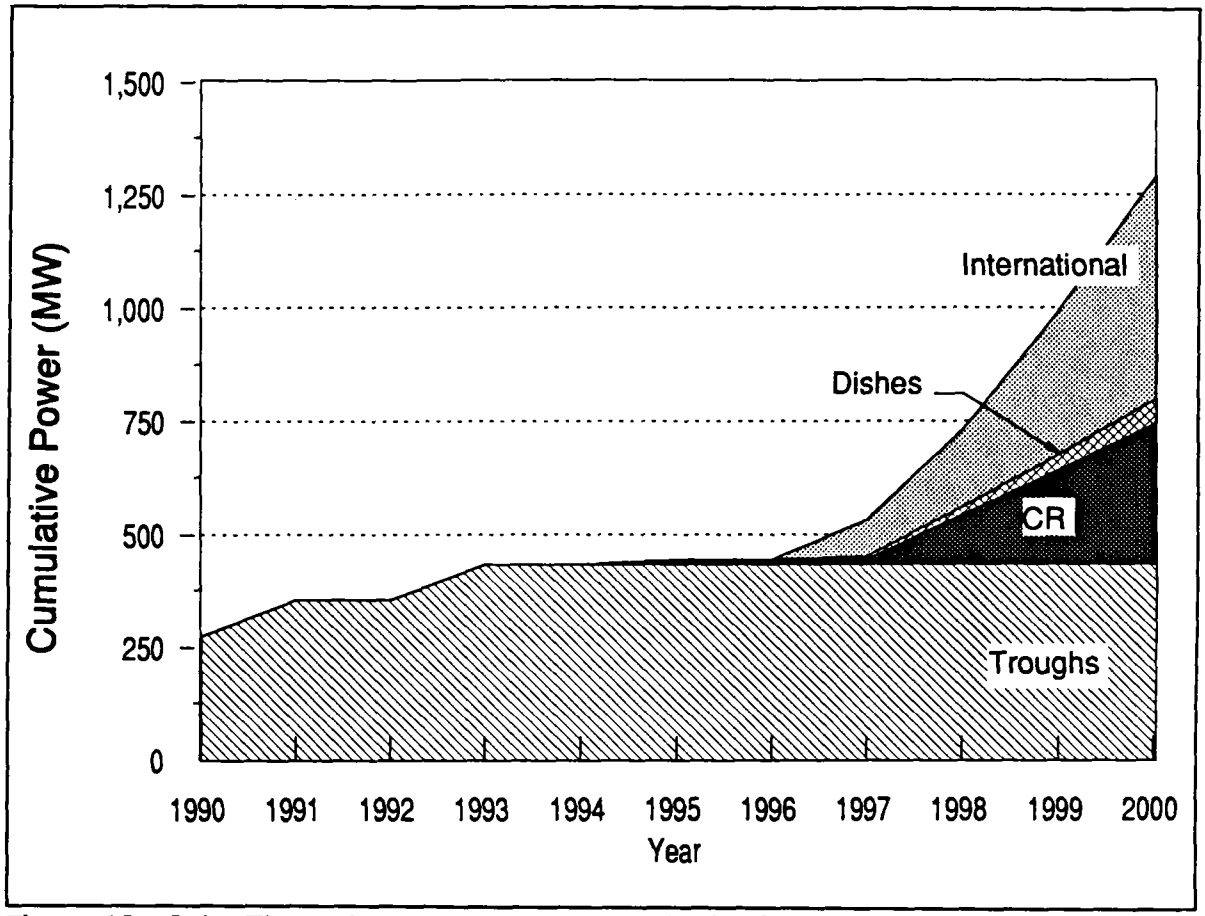


Figure 12 - Solar Thermal Market Development Projections

systems to 435 MW. Following successful operation of a small scale (10 MW) demonstration project, central receiver plants are expected to be constructed at the rate of one commercial size plant (100 MW) per year, beginning in 1998. The initial penetration of small solar dish plants into niche (on-grid and off-grid remote) markets in the U.S. and overseas is expected in the 1995-2000 period. The overseas market for U.S. solar thermal systems is expected to develop around the 1995-2000 time frame, with a mix of trough/hybrid (natural gas and/or oil) plants in the 80 MW range and smaller scale dish/Stirling engines.

- **Installation by U.S. industry of over 6000 MWe of biomass-fired capacity by 2000** (Figure 13). Today's biomass power market consists of approximately 6000 MWe of relatively inefficient Rankine cycle power (heat rate = 17,000 Btu/kWh = 20% efficiency) with approximately half of this capacity in the cogeneration sector and half in stand-alone configurations. It is anticipated that until 1994, additional steam turbine systems will be constructed with only slight improvements in heat rate and capacity factors. However, in 1994, power producers are expected to introduce and co-fire biocrudes (biomass pyrolysis oils) with fossil fuels as a means to achieve Clean Air Act-mandated sulfur dioxide emission reductions. The heat rate of these co-fire units will be approximately 10,000 Btu/kWh and total installed capacity will reach 2400 MWe by 2000. Beginning in 1995 and continuing through 2000, inefficient steam cycle cogeneration units will be retired and subsequently replaced by higher efficiency (heat rate = 11,400 Btu/kWh = 30% efficiency) gas turbine cogeneration technologies fueled with solid biomass, biomass gas, and pyrolysis

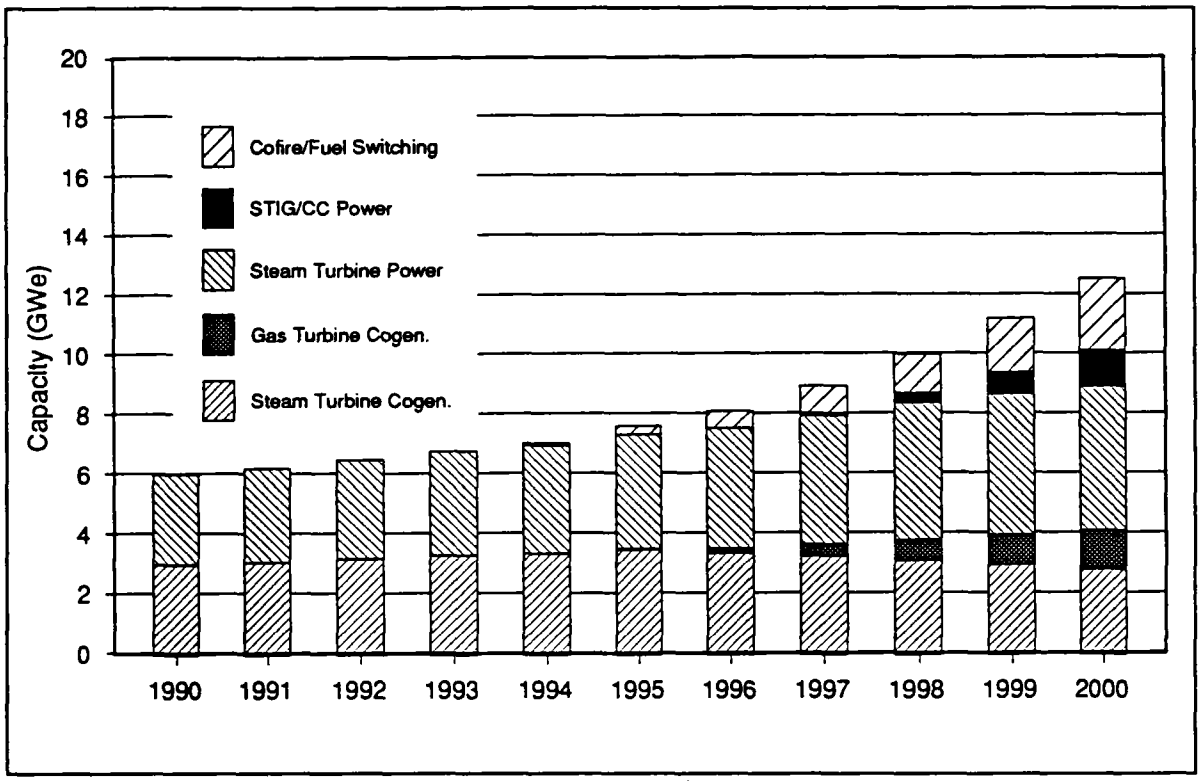


Figure 13 - Biomass Market Development Projections

oils. In the stand-alone arena, higher efficiency Rankine cycle units operating at near-base load duty cycles will continue to be installed through 2000 with heat rates approaching 12,000 Btu/kWh (28% efficiency) while the less efficient units will be retired beginning in 1999. Highly efficient (heat rate = 9500 Btu/kWh = 36% efficiency) base load steam-injected gas turbine/combined cycle units will be introduced in 1997 and will play an increasing role in capacity additions beyond 2000.

SOLAR 2000 is a robust plan which will ensure that solar electric technologies are ready for the marketplace when U.S. demand for clean power capacity is expected to surge at the end of this decade and beyond. At that time, photovoltaic, solar thermal electric and biomass electric power plants will be as commonly accepted as conventional power sources are today.

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5. A newly created SO_2 allowances market, combined with reduced SO_2 emissions limits for existing plants, has created a unique opportunity for biomass fuels. Virtually free of sulfur, biomass fuels can be co-fired with coal or high sulfur oils as a SO_2 reduction measure with minimal plant modifications. With the cost of scrubbers likely to rise as demand grows with the implementation of new Clean Air Act provisions, co-firing of biomass presents an attractive alternative.

6. P.L. 101-575.

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19. The Solar Energy Industries Association (SEIA), the National Wood Energy Association (NWEA), the U.S. Export Council for Renewable Energy (US/ECRE), the National Association of Energy Service Companies (NAESCO) and other trade groups have led a number of market conditioning efforts targeted at both the domestic and international marketplace. These include: Publishing the Green Plan, a plan of action for more rapidly deploying solar technologies; working with state regulators, utilities and others to develop a program to expand the use of PV by utilities; investigations into risk-adjusted economic evaluation models; special studies on innovative financing methods for solar conversion technologies; organizing conferences, trade missions and workshops targeted at specific groups such as utility executives, regulators, international financing organizations, non-governmental organizations, and developing country buyers; establishing a single application form for U.S. firms to access funding from the U.S. Export/Import Bank, Overseas Private Investment Corporation, Trade and Development Program, and the Agency for International Development; and setting up the International Fund for Renewable Energy and Efficiency to provide pre-feasibility study funding for U.S. industry.

20. Daniel Rich, et. al., "Photovoltaics and Electric Utilities: An Evaluation of Utility Attitudes and Expectations," in *Solar Cells*, Vol. 29, 1990, pp. 25-37.

21. Photovoltaic News, *World PV Module Shipments Increase 15.4%: European Shipments up 25%*, ed: Paul D. Maycock, Vol. 10:2, February 1991.

22. The market growth can be contrasted with the "Accelerated Growth" scenario developed by PV Energy Systems Inc. which estimated that U.S. companies could install nearly 800 MW worldwide by 2000. The corresponding growth rate requires that U.S. PV manufacturing capacity increases at about 30% per year. The SOLAR 2000 goal will require that the manufacturing capacity increase at about 38% a year, or about 25% faster than assumed by PV Energy Systems, Inc.

23. The consumer market is subdivided in "discretionary" and "durable" components. Discretionary consumer applications include PV-powered electronics; battery trickle chargers; small remote power systems for cottages, motor homes, boats, recreational vehicles; and the large number of applications where a small amount of electricity is needed for lighting, radio, TV, ventilation etc. The consumer durable market includes larger systems (e.g., 50W to 1kW) for remote homes, large boats, farms, water pumping, area lighting, etc. The commercial/industrial/agricultural market constitutes PV power for communications, lighting, signalling, monitoring, water purification and pumping, cathodic protection, security systems, navaids, etc. The government market includes similar applications as in the industrial/commercial/agricultural segment, but the buyer is state and federal government agencies. The distributed grid-connected market includes PV systems serving residences, commercial facilities, utility distributed loads such as substations where PV is used for peak load shaving. The bulk power market is centralized PV systems in the MW range. Bulk power applications prior to the year 2000 are mainly for demonstration purposes to allow utilities and PV suppliers to gain experience in serving this market sector which is expected to be the dominant market for PV post-2000.

24. For example, some utilities are already using PV to meet their own operational needs or for providing services to customers. At present, Colorado requires that electric utilities provide a cost comparison between PV and grid extension to some customers who request new connections. KC Electric in eastern Colorado installs PV water pumping in lieu of grid extension for some customers. PG&E in California has hundreds of PV systems powering small loads in their service territory.

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