SOLAR 2000: OFFICE OF SOLAR ENERGY CONVERSION STRATEGY

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ABSTRACT

The U.S. Department of Energy Office of Solar Energy Conversion proposes a three-pronged strategy to accelerate the commercial adoption of photovoltaics, solar thermal electric and biomass power technologies. This SOLAR 2000 strategy builds upon the technological progress of the 1980s to address the growing energy needs of the 1990s and beyond.

INTRODUCTION

Through SOLAR 2000, the U.S. Department of Energy's (DOE's) Office of Solar Energy Conversion (OSEC) proposes a strategy to accelerate power sector adoption of biomass electric, photovoltaic, and solar thermal electric technologies. This strategy is based on a partnership with each of the key players in the field, including the U.S. solar electric industry, 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, while concurrently, conditioning the marketplace to enhance their ability to identify, evaluate, and adopt these technologies as they become viable for particular applications.

OSEC's role is to facilitate the development of the U.S. industrial and technological base to provide proven, cost-competitive components and systems for a range of electric sector needs. OSEC will also be a partner in a number of collaborative projects with utility associations, government agencies, and industry to achieve a fully articulated market for solar electric technologies. OSEC can also provide incremental cost-sharing for projects utilizing solar electric technologies to offset externality costs in projects that yield national benefits or demonstrate the technologies for utility scale-up and/or replication. OSEC seeks to protect the investments of the federal government and work in partnership with industry to ensure that U.S.-based solar technologies are viable competitors for the domestic and international marketplace.

THE MARKETPLACE: OPPORTUNITIES FOR SOLAR ENERGY CONVERSION TECHNOLOGIES

Tremendous opportunities exist for solar electric technologies to assist in meeting the energy needs of the 1990s and beyond. In total, nearly 600 GW of new generating capacity may be required worldwide between 1990 and 2000 (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 2000s. Approximately 18 percent of the new utility-installed capacity in the U.S. will be filled by alternative energy technologies (including primarily small hydro, non-hydro renewables, multi-fuel units, and several options that are as-yet undetermined or unplanned) (4).

Domestically, the western U.S. and the state of Texas expect an unplanned capacity requirement of approximately 3 GW each over the period 1990-2000. Both of these regions have strong solar resources. The southeastern U.S., with its high solar and biomass resources, has a corresponding unplanned capacity requirement of nearly 6 GW. The northeast, with substantial biomass resources, has an unplanned capacity need of almost 5 GW. These requirements are in addition to significant investments needed for life extension and repowering of current installed capacity, estimated to be around 340 GW in the next 20 years (5). Almost 160 GW of existing capacity will pass its 50th birthday in the period 2000 to 2010 (6). Of this capacity, nearly one-third will be in the South and another quarter will be in the Midwest. Overall, for over two-thirds of the utilities in the U.S., generating requirements are expected to grow at or less than 100 MW per year, with more than 88% of the utilities having requirements of less than 250 MW per year. Because solar conversion plants are typically less than 200 MW each, they are well suited to meet these smaller-scale utility requirements. In many instances these capacity additions could be delayed by implementing strong efficiency and demand-side management programs, where solar conversion technologies could also play a key role.

In the international marketplace, the next 10 years anticipate the need for nearly 500 GW of generating capacity. Developing countries alone will require about

Figure 1. Worldwide Electric Power Capacity Needs for New Generating Capacity

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. Assuming an average cost of roughly \$1,000/kW for new capacity and half that for repowering, this represents an investment of nearly \$600 billion with the largest potential market overseas.

In spite of these capacity increases, a large proportion of rural communities in developing countries will continue to lack access to electric power due to the cost and difficulty of extending transmission and distribution systems to dispersed communities. The power requirements of most nonelectrified rural communities in developing countries are modest with primary batteries, kerosene (for lighting), and gasoline and diesel generators providing most of the energy. The aggregate remote electric power requirements are huge -- there are 10 million small (less than 200 kW) diesel generators operating in the sunbelt around the world with 2 million new generators sold annually (7). The modularity, ease of maintenance, and independence from fuel supplies makes several solar conversion technology configurations ideally suited for remote and dispersed applications.

THE OPERATING ENVIRONMENT

Complementing this demand for new generating capacity and energy efficiency is an emerging market scenario that lays the groundwork for innovative technology solutions. This is demonstrated by:

- Heightened awareness on the part of utilities, end-users and regulators that improved delivery of electricity services can be accomplished through a mix of central generation/transmission, distributed generation, and off-grid power supply. This trend is assisted by a greater emphasis on integrated resource planning, modular alternative energy technologies, energy efficiency, and demand-side management (DSM).
- A trend toward smaller, incremental capacity additions for U.S. utilities, implemented by either independent power producers or by the utilities themselves.
- Increased activity by non-utility wholesale power generators, including utility business subsidiaries. These groups are less constrained than investor owned utilities (IOUs) in their choice of generating technology, the legal and administrative requirements, and risk taking.
- Development of a U.S. National Energy Strategy in 1991 that calls for enhanced R&D funding for renewable technologies -- thereby demonstrating a long-term federal commitment to these technologies.
- Rising concern over the environment as exemplified by the Clean Air Act Amendments of 1991, another 100 environmental legislative initiatives, and numerous state-sponsored environmental regulations.
- Changes to the Public Utility Regulatory Power Act (PURPA) (8) in combination with proposed Public Utilities Holding Company Act (PUHCA)

modifications which could expand the role of solar conversion technologies. There is a concern, however, that if key issues such as transmission access are not resolved, these regulatory changes could be detrimental to solar conversion technology projects.

- Recognition by the Federal Energy Regulatory Commission (FERC) and state regulators of the inadequacy of existing regulations to provide utility incentives for investments and cost-sharing innovations (9).
- Enhanced business and political climate for deployment of solar electric technologies as indicated by Congressional action in March 1991 to authorize \$100 million for the deployment of 10 PV demonstration projects (each at least 10 MW in size) (10). Subsequently, Congressional action in June 1991 recommended at least one joint-venture for a utility-scale 10 MW PV project with an authorization of \$27 million during FY92-94 (11). Also under consideration are a joint-venture program for biomass combustion/gasification at \$3 million per year for the next 3 years (12), and a renewable electricity production tax credit for new capacity (13).

As the conditions for doing business in the power generation market continue to evolve, the opportunities for using more efficient and environmentally acceptable power generation technologies, such as solar electric, should be enhanced.

CURRENT SUPPLY OPTIONS

In Figure 2, screening curves for new plants with the economics of utility ownership are provided for current technology. Screening curves plot the 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. Current choices of commercial solar-powered generation plants for utility applications have been limited to biomass-fired and solar parabolic trough steam turbine installations. Commercial solar plants in Figure 2, are shown as cost bands due to the wide variation in cost and performance depending on many factors including availability of tax and regulatory incentives. Although these options are not widely competitive with the conventional power options, the solar parabolic trough subcritical steam power plants on the Southern California Edison grid and the many small capacity wood/waste-fired plants throughout the country, have demonstrated there are a number of early markets with special characteristics that have already resulted in successful commercial ventures. Several regions of the country have solar resource characteristics that will assist development of early markets (the Southwest for PV and solar thermal, the southeastern

Figure 2. Utility Plant Options for 1991

and northern states for biomass). In international markets, PV generators in hybrid and stand-alone configurations have made their mark all over the world. With PV currently in the lead as the export solar technology, manufacturers of other solar technologies are likely to follow suit in the 1990s.

NEXT GENERATION POWER PLANT OPTIONS - MODULAR PLANTS

By the latter half of the 1990s, improvements to the technology, implementation of valuation methods to account for environmental externalities, and integrated resource planning will alter the planning picture for new generation sources. Figure 3 shows screening curves for both modular (less than 100 MWe) and intermediate-sized (100-200 MWe) plants. The smaller plants 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 conversion 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 also likely to be a competitive player, particularly in niche power markets where zero emissions are desirable.

Figure 3. Capacity Addition Options in 1998

NEXT GENERATION POWER PLANT OPTIONS - INTERMEDIATE SCALE PLANTS

Figure 3 also compares screening curves for intermediate-scale plants. At this scale central receivers and biomass-fired combined cycles, such as the integrated gasification, intercooled, steam-injected gas turbine, are expected to be very competitive in the intermediate and baseload range. The zero emissions characteristic of the solar thermal central receiver plant is likely to be an important factor in competitive bidding in a number of southwestern utility service areas. One option that potentially cuts across most of the load types and source options is the production of liquid fuels from biomass or coal.

MEETING LOAD GROWTH WITH DISPERSED POWER SUPPLIES

Figure 4 provides a view of meeting power needs on the customer side of the meter. It compares current costs for electric service (on a per kWh basis) during periods of peak system demand, to the cost of on-site power generation. As shown, rates for power consumption during times of peak demand are very utility specific. To encourage load control (Demand Side Management) and recoup the expense of providing power for peak loads, residential, commercial and industrial customers are now paying a premium for power used during periods of peak demand. 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. Small PV and Dish Stirling power supplies will compete with diesel generators in this market, with the substantial advantage of zero emissions (or very low emissions in hybrid configurations) and quiet operation.

Figure 4. Demand Side Power Supplies

Utilities have taken varied approaches to promoting the implementation of DSM policies. These range from giving away high-efficiency fluorescent lamps, to providing technical assistance and rebates for customer owned and operated load control measures. Since the primary business for utilities is in generating and selling electricity, one potential approach for DSM is to involve power companies in the installation, owning and operating of on-site power generators during peaking hours. Power companies or customers could own on-site generators that would provide both standby generation capability, and a new distributed source of dispatchable power for the utility grid.

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. Avoided utility costs accrue both to savings in generation, transmission and distribution equipment capacity additions/improvements, as well as to increased reliability of customer service. As demonstrated in Figure 5, 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 5 are those projected for the post-1995 time frame, PG&E reports that current PV systems could be marginally competitive today in optimum locations.

PROVIDING POWER TO REMOTE LOCATIONS

Areas not currently serviced by utility grids (remote areas of the industrialized nations and most rural areas of the

MATCHING THE TECHNOLOGY TO THE MARKETPLACE: THE ROLE OF U.S. INDUSTRY

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, operation and maintenance. The U.S. industry has achieved international leadership in research, technical performance of its products, and market dominance in a number of niche markets. The industry ranges from small start-up ventures to large divisions of Fortune 500 companies.

Although there are a number of successful U.S. solar electric companies, the industry is characterized for the most part by small and medium firms that are not yet profitable. U.S. photovoltaic industry sales exceed \$100 million annually with about a 15% annual growth rate. About 40 PV companies supply a complete range of services from cell fabrication, system engineering and installation to construction of turnkey manufacturing plants. Their principal market is off-grid remote power applications. Today's solar thermal industry consists mainly of companies pursuing R&D and demonstrations, and one company, Luz International Ltd., with sales in the utility-scale electric systems market (over 350 MW in place, and contracts for another 320 MW). There are approximately 30 different companies involved in developing biomass-fired generation for sale to electric utilities or to industrial facilities. Most of today's biomass power installations are smaller-scale independent power and cogeneration systems; utilities have not been major developers of biomass-based plants.

Through the 1980s, the U.S. biomass industry experienced significant growth, from 200 MW in 1979 to 7,800 MW installed by 1989 due mainly to PURPA and federal tax incentives. By the end of the 1980s, however, this rapid growth of the biomass electric industry had slowed significantly; the biomass electric industrial output is currently around 200 MW/year.

The solar electric industry is at a crossroads. Given the boom-and-bust cycles of the past, industry is reticent to embark on a major investment program without stronger signals from the marketplace that there will be a stable expansion of the demand for solar conversion technologies. U.S. industry has the capacity to respond to accelerated market needs. To achieve this needed growth, capital must flow to industry; R&D achievements must be transferred to production lines; and production capacities must be expanded. Resources to mitigate regulatory, educational, and financial barriers that hinder market expansion must be allocated. There are factors which are beyond industry's control, however, such as declining oil prices, loss of tax credits, and shifts in the implementation of PURPA toward competitive bidding and acceptance of large independent

Figure 5. Distributed Power Supplies - An Option to Substation Upgrade

less developed countries) are prime targets for modular renewable energy power systems. The modularity, ease of maintenance, and independence from fuel supplies makes solar conversion technology such as PV and dish electric systems ideally suited for remote and dispersed applications. Figure 6 indicates the economics of these systems relative to diesel gensets and grid extension.

Figure 6. Remote Power Supply Options

power producers. The recent financial difficulties of Luz exemplifies the predicament faced by many solar companies. The industry also faces strong challenges from foreign competitors, especially European and Japanese companies, in manufacturing, marketing and sales. The U.S. share of the world PV market, for example, has declined from 60% in 1983 to approximately 30% in 1990.

There are encouraging signs that market conditions are improving due to better products entering the market, greater awareness among the customers regarding the potential of solar conversion technologies, and stronger commitment toward environmentally cleaner technologies by state, federal and international agencies. Solar 2000, through a combination of demand enhancement, product development, and improvement of the market and regulatory environment, will support the U.S. solar conversion industry's efforts. As a result, considerable benefits will accrue to the nation including a cleaner environment; a stronger, more diverse, high technology industrial base; a larger portfolio of energy supply technologies; world market leadership; enhanced employment opportunities; and increased energy security.

THE OSEC ROLE AND COMMITMENT

The OSEC role is to serve as a facilitator to bring producers and users together to rapidly achieve a fully articulated market for solar electric technologies.

Clearly, the decade of the 1990s represent enhanced market penetration and commercialization for solar conversion technologies using the technological progress achieved during the decade of 1980s. Although the opportunities for solar electric deployment exist and the technologies are in place, these options are not seriously considered in mainstream utility and other customer planning decisions. To mitigate the barriers which hinder technology advancement, a number of activities need to occur. These include:

- Increased research and development funds to further improve the efficiencies and performance of the technologies, reduce costs, and scale up manufacturing and production.
- Conditioning of the marketplace, particularly in the regulatory and policy areas, to encourage more equitable consideration of solar electric technologies.
- Project development and implementation to provide information on the performance, availability, operation and maintenance costs at user sites to enhance the acceptance of the technologies by the customer.
- Increased education, promotion, and technology transfer activities.

Undertaking these initiatives will require collaboration between each of the key players -- utilities and other end-users, the solar conversion industry, regulators, and the government. OSEC, with its strong ties to each of these groups, as well as its national mandate on energy issues, can support industry in promoting solar electric commercialization and adoption. 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. In this context, OSEC is in a position to support technologies which 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.

SOLAR 2000 GOAL AND STRATEGY

The SOLAR 2000 goal is to accelerate the commercial use of solar electric technologies by the power sector, and to assist the solar conversion industry to meet this growing energy demand in the near-, mid-, and long-term. These goals will be accomplished by:

- Advancing technology through collaborative research, development and demonstration (RD&D) with industry;
- Encouraging a broader acceptance of U.S. solar conversion technologies by the electric power sector to benefit the economic competitiveness, energy security, and environmental quality goals of the nation; and,
- Increasing the use of currently available and newly emerging cost-effective alternative solar energy conversion technologies.

By the year 2000, SOLAR 2000 expects to facilitate:

- a) The deployment of 1,400 MW of U.S.-made PV systems worldwide, with about 900 MW installed in the U.S. and 500 MW installed overseas between 1991 and 2000;
- b) Installation of 1,800 MW of U.S. solar thermal electric systems worldwide, with 1,300 MW in the U.S. and 500 MW overseas during 1991-2000; and
- c) Installation by U.S. industry of 4,000 MW of biomass electric power systems in the U.S. and about 3,000 MW overseas between 1991-2000.

The SOLAR 2000 strategy involves coordinated action on three fronts which combine to address existing barriers in the electric power supply marketplace, both domestically and overseas. The three-pronged strategy consists of:

- (1) Technology Development and Validation. Technology development and validation efforts will focus on proof-of-concept activities relevant to emerging OSEC electric technologies and their performance validation. By advancing technologies through collaborative research, development, and demonstration with industry, OSEC will promote more reliable, durable, and cost-competitive solar conversion systems in the marketplace. This component includes synchronizing the RD&D effort with the needs of users, expanding the availability of resource data, and improving system performance along several parameters.
- (2) Market Conditioning. By laying the groundwork with potential buyers, OSEC will help overcome the remaining obstacles to market acceptance of solar energy conversion technologies. This component dedicates resources toward building the infrastructure whereby decision-makers can identify and evaluate practical applications for solar conversion systems; where solar conversion system characteristics are incorporated into existing decision tools (e.g., system expansion planning models and methods for evaluation of competitive bids for new capacity); and the benefits of solar power generation can be quantitatively appraised in light of federal, state and local environmental regulatory requirements.
- (3) Project Development. The project development strategy is targeted at proving that solar conversion technologies can fully meet cost, performance and reliability requirements of the customers. By leveraging resources in conjunction with private-sector commitments, OSEC will collaborate with other stakeholders to provide the momentum and the experience base necessary to meet the SOLAR 2000 goal. DOE and OSEC will continue to work in partnership with the U.S. private sector by assisting in leveraging successes. In addition, both DOE and OSEC will continue to provide technical assistance for project identification, evaluation, design and implementation, and leverage funding for innovative projects.

Although technology development and validation initiatives will cut across a range of technology issues and end-user requirements, the market conditioning and project development activities are more targeted in nature.

SUCCESS BY 2000: A JOINT PUBLIC/PRIVATE COLLABORATION

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, policy-makers, and other stakeholders. OSEC will work closely with key organizations critical to the ultimate success of this strategy. OSEC brings R&D funding, technical expertise, market conditioning support, and funds and technical assistance for cost-shared demonstration projects. Industry provides technical expertise, R&D funds, manpower, and facilities; expanded manufacturing capabilities; and technically proven, cost competitive products and services. Regulators and policy-makers help shape the regulatory and legislative playing field towards more equitable consideration of solar technologies. Utilities, other users, and investors create the demand for solar conversion technologies and bring the capital and support for technology demonstration and project implementation. By building upon the individual strengths of each of the players, OSEC can ensure that the SOLAR 2000 objectives are met in a cohesive and effective manner, making optimal use of limited resources.

Through continued research and development and new commercialization initiatives, the 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 cooperation to offer cost-effective alternative energy options to utility and other customers. For its part, the DOE is in a position to public agencies to bring producers and end-users together in an effort to catalyze and expedite the further rapid commercialization of solar conversion technologies. Our approach selectively applies public resources toward addressing the shortcomings inherent in any emerging, high technology market.

SOLAR 2000 is a robust plan that will ensure that solar conversion technologies are ready for the marketplace when U.S. demand for clean power capacity is expected to surge in the year 2000 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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