Utility Grid-Connected Distributed Power Systems

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ABSTRACT

The utility grid-connected market has been identified as a key market to be developed to accelerate the commercialization of photovoltaics. The Sacramento Municipal Utility District (SMUD) has completed the first three years of a continuing commercialization effort based on the sustained, orderly development of the grid-connected, utility PV market. This program is aimed at developing the experience needed to successfully integrate PV as distributed generation into the utility system and to stimulate the collaborative processes needed to accelerate the cost-reductions necessary for PV to be cost-effective in these applications by about the year 2000. In the first three years, SMUD has installed over 340 residential and commercial building, grid-connected, rooftop, "PV Pioneer" systems totaling over 1.4MW of capacity and five substation sited, grid-support PV systems totaling 860 kW bringing the SMUD distributed PV power system to nearly 5 MW. SMUD also established a partnership with its customers through the PV Pioneer "green pricing" program to advance PV commercialization and to develop rooftops as "PV power plant" distributed generation sites.

1. INTRODUCTION

The Sacramento Municipal Utility District (SMUD) is the fifth largest public utility in the nation and serves a 900 square mile area in and near Sacramento County, California. SMUD plans to have at least half of its energy obtained from energy efficiency and renewable resources by the year 2000. Solar energy will provide an important part of both the "DSM/Energy Efficiency Power Plant" and renewable energy, distributed generation resource. Investments made in solar power today are expected to provide the customer-owners of SMUD with substantial long-term energy and community benefits.

The SMUD Solar Program has three elements designed to increase Sacramento's use of solar energy. The Solar Domestic Hot Water Program uses attractive performance based rebates and financing and strict quality assurance requirements to encourage the electric water heat customer to switch to solar water heating. Since May 1992, over 3000 SMUD customers have used this program

and reduced their electric water heating energy consumption by an average of 60% and provided the District with needed peak capacity and energy benefits. The Solar Buildings Program provides design assistance and incentives to encourage the incorporation of cost-effective passive and other solar features in the design and construction of both new buildings and the retrofit of existing buildings. The Solar Buildings Program is also responsible for collaborative solar cooling development and demonstration projects.

The Solar Electric Program includes solar thermal electric systems, such as the Solar Two Central Receiver Project and the Utility-scale Solar Dish/Stirling Engine Joint Venture, and a wide variety of photovoltaics applications aimed at the accelerated commercialization of grid-connected PV systems.

2. **SMUD PV PROGRAM**

SMUD has embarked on an ambitious commercialization effort based on the sustained, orderly development of the grid-connected, utility PV market. This program is aimed at developing the experiential base needed to successfully integrate PV as distributed generation into the utility system and to stimulate the collaborative processes needed to accelerate the cost-reductions necessary for PV applications to be cost-effective in these applications.

SMUD is playing a leadership role in the commercialization of grid-connected PV through its own PV programs as well as helping to developing the collaborative State and national utility PV commercialization efforts underway including the Utility Photovoltaic Group (UPVG) and Photovoltaic for Utilities (PV4U) programs.

SMUD is a leader in utility grid-connected applications of PVs with the world's largest distributed PV power system. The SMUD PV system, currently nearly 5 MW, includes SMUD PV1/PV2 (2 MW operating since 1984, figure 1), the first public PV electric vehicle recharge station in the West, residential grid-connected PV installations, and numerous remote power and sensor applications including a number of PV powered street lights and PV powered, emergency phones. In 1993 SMUD adopted a long-term PV commercialization strategy aimed at accelerating the cost-reduction of grid-connected utility PV applications.

Figure 1. SMUD's 2 MW PV generating station at site of the closed Rancho Seco nuclear plant. Established 1984.

As part of this effort SMUD installed in 1993 716 kW of grid-connected PV systems. These systems include 109 4 kW (400 kW total) residential, roof-mounted PV systems; a 30 kW commercial building sited, concentrating PV system; and a 258 kW substation sited, distribution support PV system. The 1994 SMUD PV Program included 889 kW of grid-connected PV systems. These included 400 kW of residential rooftop, 144 kW of commercial rooftop, a 3 kW demonstration building integrated, PV roofing system and 3 substation projects totaling 342 kW. The 1995 SMUD PV Program included 845 kW. These included 416 kW of residential rooftop systems, a 263 kW substation system and two PV parking lot systems (166 kW).

Both the 1994 and the 1995 PV Projects include USDOE/UPVG TEAM-UP cost-share funding. The 1995 additions will bring the SMUD Distributed PV System to nearly 5 MW (Table 1).

2.1 **Rating of PV Systems**

SMUD has adopted a convention of rating the effective kW output of grid-connected PV systems based on national utility standards. All PV systems, unless otherwise noted, are rated based on the AC output of the system at PVUSA test conditions (kW, AC, PTC). PVUSA Test Conditions (PTC) are used by the utility industry and specified by UPVG. PTC ratings are typically 10% more conservative than the Standard Test Conditions (STC) ratings used by the PV industry.

To account for the differences in energy production between fixed and tracking PV systems, the Energy Production Factor, EPF, has been adopted. Established by the Utility Photovoltaic Group (UPVG), the EPF factor permits a more appropriate comparison between fixed and tracking systems. This permits the conventional comparison of $/W to attach value to the additional energy production value of tracking as well as accounting for the added cost. SMUD rates tracking PV systems based on the AC output of the system at PVUSA test conditions with the Energy Production Factor adjusting the nominal output of the system (kW, AC, PTC, EPF).

Table 1: SMUD PV Projects through 1995

1980s: 2460 kW,EPF	Rancho Seco PV1: 1000kW (1230kW.EPF)	Arco System (1984) Rancho Seco PV2: 1000kW (1230kW.EPF)	Arco/Solarex/ Mobil (86)			
1993: 716 kW,EPF	PV Pioneers 93: 400kW, 108 3-4kW Siemens Systems (1993-94)	Hedge PV1: 210kW (258kW,EPF) UPG/Siemens System (1993-94)	SMUD Warehouse PV: 30kW (37kW,EPF) SEA System (1993-96)	PVEV Charging Station: 11kW Arco System (1992)	PV Res Demo Systems: 10kW Various (1992-93)	
1994: 889kW,EPF	PV Pioneers 94: 400kW, 119 3-4kW Solec Systems (1994-95)	PV Pioneers Commercial 94: 144kW, 8 10-30kW Solec (1994-95)	Hedge PV2: 108kW APS System (1994-95)	Hedge PV3: 102kW RMI/ Solarex System	Hedge PV4: 107kW (132kW,EPF) UPG/ Siemens System	WAPA BI-Roof Demo: 3kW (1994)

				(1994-95)	(1994-95)	
1995: 845kW,EPF	PV Pioneers 94/95: 87kW, 25 3-4kW RMI/Solarex Systems (1994-95)	PV Pioneers 95: 329kW, 80 3-4kW Placer/ Solarex Systems (1995-96)	Rancho Seco PV3: 214kW (263kW,EPF) UPG/Siemens (1995-96)	PVEV Airport: 8kW Arco System (1995-96)	PV Solar Carport: 128kW (158kW,EPF) UPG/ Siemens (1995-96)	
Total PV on system: 4.9MW,EPF (4.3MW, Nominal)						

2.2 **Residential PV Pioneer Project**

The 1993 SMUD PV Pioneer Project established a partnership with customers willing to assist in the early adoption of photovoltaic (PV) technology. Under the PV Pioneer Program, SMUD purchases, installs, owns, and operates 100+ residential rooftop PV systems, each about 4 kW, each year (Figure 2 and 3). SMUD plans to continue adding at least 100 PV Pioneer systems each year for 5 years.

Figure 2. SMUD Residential PV Pioneer (System).

SMUD customers (the PV Pioneers) volunteer to share in this effort through a form of "green pricing" and by providing the roof area to place the environmentally friendly, solar electric generation PV systems. The PV Pioneer pays a $4 per month premium (about 10 to 15% of the average electric bill) on their utility bill to participate. In doing so, the PV Pioneers have the satisfaction of generating clean, renewable energy on their own rooftops. SMUD gains experience in the installation, operation, maintenance, pricing strategies and other aspects of residential PV systems and obtains low-cost "power plant sites." This joint effort also helps accelerate the commercialization of PV as part of a process of sustained, orderly development.

The 1993 PV Pioneer systems were supplied as 108 turn-key, installed systems totaling 400 kW by Siemens Solar Industries (SSI) for $7.70/W AC, PTC. The 4 kW systems make up a standard 400 square foot array. A few systems were down-sized to accommodate homes with smaller roof area. Innovative roofjacks permitted quick installation of the PV array. The complete PV system installation requires only half of a day. The PV system parallels on the utility side of residential service meters

and enters the utility grid through a separate utility meter mounted next to the house utility meter.

The 1994 PV Pioneer systems were supplied by Solec International, Inc. as 109 3.7 kW systems with Omnion invertors at a turn-key cost of $6.23/W.

The 1995 PV Pioneer Program included Resource Management International and Solarex supplying 25 3.5 kW systems with Pacific invertors contracted for in 1994 at a turn-key cost of $6.98/W. An additional 80 4.1 kW systems (329 kW) from Placer/RMI/Solarex using Trace invertors at a turn-key cost of $5.98/W were contracted for in 1995. These systems were installed on residential and commercial rooftops in late 1995 and early 1996.

Figure 3. Installation of PV Pioneer System

2.3 **Customer Attitudes and Response to PV Green Pricing**

It is up to local communities, states, the utilities and the public at-large to take the lead in demanding and providing the extensive use of solar energy. A March 1993 scientific market research survey showed that the people of Sacramento are interested in helping to lead the way to a cleaner, sustainable future. The following survey results demonstrated the willingness of SMUD customers to support "green pricing" programs for PV.

Willing to pay a premium price (15%) for PV generated electricity from their rooftops: 26% of the general, and 57% of the "green" population.

Willing to pay a premium (15%) with rate stabilization of the PV portion: 49% of the general, and 77% "green" population.

Willing to participate in a general "green pricing" program of 1 to 10% of the utility bill to for a "Clean Energy" program District wide (not necessarily on their own roof): 70% of the general, and 88% "green" population.

The customer response to the PV Pioneer Program has greatly exceeded expectations with about 1000 customers volunteering each year. Of these, about 600 pass the pre-qualifying screen and agree to pay the PV Green Fee premium. From this pool, the 100+ PV Pioneers for each year are selected. With the restrictive roof requirements, qualifying rooftops have been a much greater constraint to volunteers than the "green fee".

2.4 **Commercial Building Sited PV Systems**

This project provides for the installation of PV Pioneer systems on commercial rooftops. The first system, started in 1993 and completed in 1995, is a nominal 30 kW, single axis tracking, concentrating PV system uniquely adaptable to roof-top applications installed on the SMUD 59th Street Warehouse. This tracking system has an effective rating of 37 kW, EPF. The system by Solar Energy Applications Corp. (SEA), is a roof mounted single axis tracking, concentrating PV system with a south orientation at a 38 degree pitch. The system uses 10X concentration fresnel lenses focused on the PV cells and covers 4000 square feet of roof area. The system price of this demonstration project is $7.41/watt, EPF.

The 1994 SMUD PV Program installed in 1994 and 1995 flat plate PV Pioneer systems on commercial building roof-tops totaling 144 kW by Solec for $6.25/W. These Commercial PV Pioneers include a 24 kW system on a VFW Hall and a 30 kW system on the Wilton Bible Church (figure 4) and five additional systems of various sizes installed on church roofs. Each requires about 100 square feet of roof area for each kW.

Figure 4. 30 kW Wilton Bible Church Commercial PV Pioneer System.

2.5 **Building Integrated and Parking Lot Sited PV Systems**

The 1994 PV Program installed a 3 kW building integrated PV demonstration system in partnership with the Western Area Power Administration (WAPA, Figure 5). The PV system is integrated in the reroofing structure installed on a WAPA office building. The PV roofing tile system is part of the roofing system installed to insulate and protect the roof membrane. The "Powerguard" PV system in being designed and installed by Powerlight Corporation and Western Single Ply, a commercial roofing contractor. A full size, 40 kW system is scheduled for installation in 1996 on another WAPA building.

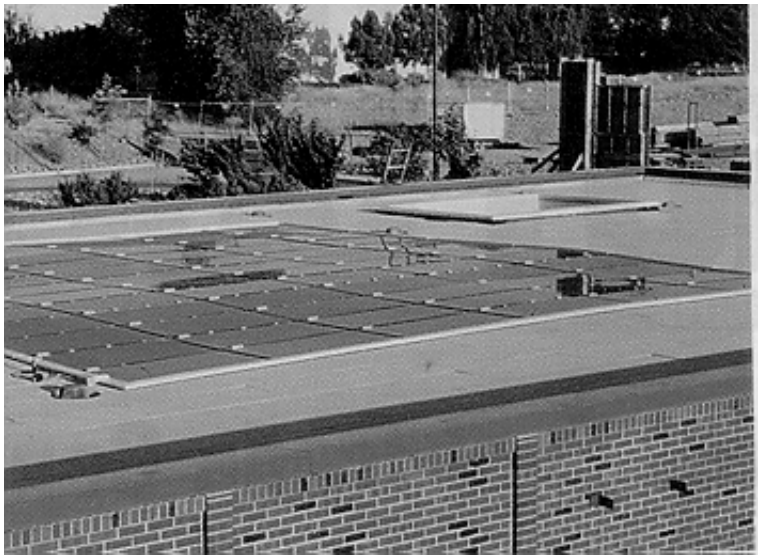


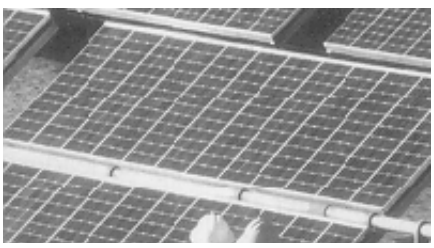
Figure 5. SMUD/WAPA Building Integrated 3 kW PV Roofing System

Solar Design Associates and Solarex are scheduled to complete in early 1996 a demonstration of an AC PV Module system. The AC PV module incorporate the invertor as part of the PV module. This permits the PV system to be built up an AC building blocks. Two residential PV Pioneer systems are being completed with these AC PV modules. This demonstration is part of a DOE PVBONUS supported project.

In 1994, the lowest bid received by SMUD for a parking lot sited PV system was for nearly $10/W. While the development of parking lot air space for PV energy production is of very high priority to SMUD (and especially important in urban/suburban areas) the price was too high. In 1995 Utility Power Group bid a 158 kW, EPF parking lot sited PV system. This system is a single axis tracking system and costs $6.36/W, EPF. The installation at Sacramento Municipal Airport is scheduled for completion in Spring of 1996. A smaller 8 kW parking lot system was also installed at the airport site.

2.6 **Substation Sited, T&D PV Systems**

The 1993 project installed a 258 kW, EPF (210 kW nominal) ground mount, single axis tracking PV system at the SMUD Hedge Substation. The installation of this PV system demonstrated the ability and versatility of placing medium size PV systems for District distributed generation benefits. The system is located at the Hedge Transmission and Distribution training yard and connected to the 12kV distribution system. The system was designed and installed by Utility Power Group (UPG) and is a single axis tracking 258 kW, EPF PV generation plant. SMUD provided the site preparation and utility grid interconnection. The turn-key system price was $7.70/watt (nominal) compared to $8.90/ watt for the PG&E 500kW Kermin PV plant completed in Spring 1993. The system (figure 6) is a ground mount, flat plate, single axis tracking system utilizing Siemens solar modules. A 250 kW Omnion inverter/transformer converts 720 VDC to 12.47 kVAC for grid interconnection. Accounting for the increased production due to tracking (using the Energy Production Factor, EPF) the effective price was $6.26/W AC,EPF. The system was completed in early 1994.



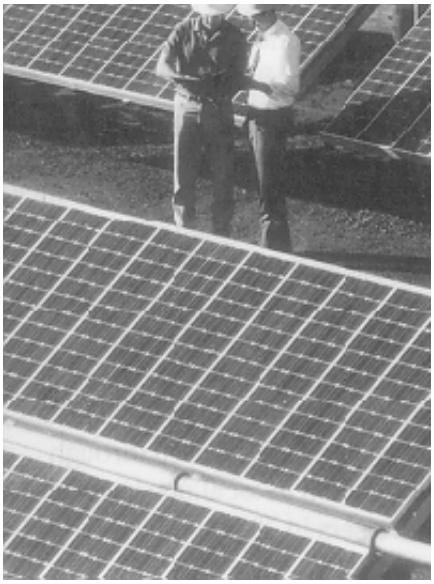


Figure 6. 210 kW SMUD Hedge Substation PV system.

Three additional PV power stations at the Hedge site totaling an additional 317 kW were installed under the 1994 program and completed in 1995. Bell Products, Inc. and Advanced Photovoltaic Systems, Inc. supplied a fixed, 108 kW system using the APS thin-film module and a Kenetech invertor at a cost of $6.68/W. Resource Management International and Solarex supplied a fixed, 102 kW system using Solarex modules and a Kenetech invertor at a cost of $7.35/W. Utility Power Group and Siemens Solar supplied a 132 kW, EPF (107 kW nominal) single axis tracking system using Siemens modules and multiple UPG invertors at a cost of $7.50/W, nominal or $6.10/W EPF.

The 1995 substation PV project is a 263 kW, EPF (214 kW nominal) single axis tracking system by Utility Power Group. This system has a turn-key price of $5.71/W, EPF ($7/W nominal) and is scheduled for completion Spring 1996.

2.7 **1993 - 1995 SMUD PV Program Cost Improvements**

The 1994 SMUD PV Program systems showed substantial cost improvements over the 1993 projects. This improvement has continued into 1995. This is true both for the turn-key contract costs as well as for the costs incurred by the utility to develop, procure, administer, and perform the Utility side of the systems installation and integration into the grid, as can be seen in the following table for the residential (RES) and substation (SUB) systems.

1993 - 1995 SMUD PV COST IMPROVEMENT

TURN-KEY SMUD4 TOTAL 30 yr

PROJECT-YR	COST1	ADD COST	COST	¢/kWh[5,6]
SUB - 1993[2]	$6.26/W	$3.89/W	$10.15/W	32¢
SUB - 1994[3]	$6.68/W	$1.07/W	$ 7.75/W	21¢
SUB - 1994[2]	$6.10/W	$0.87/W	$ 6.97/W	19¢
SUB - 1995[2]	$5.71/W	$0.91/W	$ 6.62/W	18¢
RES - 1993[3]	$7.70/W	$1.08/W	$ 8.78/W	23¢
RES - 1994[3]	$6.23/W	$0.90/W	$ 7.13/W	20¢
RES - 1995[3]	$5.98/W	$0.89/W	$ 6.87/W	18¢

1. Turn-key contract cost up to utility interconnection without tax, bonding or utility add-on costs.
2. Single axis tracking system. Includes credit for Energy Production Factor (EPF) [for single-axis tracking, EPF = 1.23 compared to fixed tilt].
3. Fixed, non-tracking system, EPF = 1.00
4. Includes: interconnections, metering, site preparation, District labor, administration, overheads, tax, bonding, AFUDC, and other costs.
5. Includes: O&M, does not include DOE cost-share.
6. Preliminary estimate.

2.8 **The Roof-top Resource**

In metropolitan areas, hundreds of thousands of square acres of residential and commercial roof area, parking lots and transmission corridors are setting unused in the sun. As Skip Fralick of San Diego Gas & Electric Company pointed out, "This rooftop area is the equivalent of "free land" for photovoltaic generation: it needs no development, environmental impact statements, or extensions of transmission lines." In Sacramento alone, these south to west oriented roofs, parking lots and transmission corridors represents the potential of hundreds of megawatts of photovoltaic resource.

Power plant siting is normally a troublesome, time consuming and expensive exercise, especially in a suburban or urban area. However, over the past three years, SMUD has sited about 340 PV power plants all across Sacramento with little trouble or expense. Indeed, hundreds of customers have paid extra on their utility bill to host a SMUD PV power plant on their roof. This ease of siting combined with the environmental, modular and distributed benefits of PV add substantially to the value PV brings to the utility's energy mix.

3. **A UTILITY PERSPECTIVE ON PV COMMERCIALIZATION**

There is a critical need to accelerate and complete commercialization of PVs to meet our needs for grid-connected, utility applications for year 2000 and beyond. Without a concerted and collaborative effort we can not assume that PVs will be ready to serve the utility market when we will need it. Our actions today are our investments for tomorrow.

The off-grid, "currently cost-effective" PV applications are not sufficient to commercialize and make cost-effective the grid-connected, utility PV applications. We must continue the process of the grid-connected market development directly. These grid-connected applications have value beyond energy and capacity and include residential and commercial customer sited PV for distributed generation and DSM applications and substation/T&D sited PV for grid-support value.

There are three central concepts necessary to achieve the production levels and cost reductions required for the accelerated commercialization of photovoltaics for utility systems:

- Sustained Orderly Development (SOD)
- Commercialization path life-cycle costing
- Proactive leadership to stimulate early adoption

3.1 **Sustained Orderly Development (SOD)**

The solar industry needs a reliable and longterm market volume to develop and achieve longterm cost reductions required for full commercialization. Current "costeffective" utility markets have not

provided sufficient market volume to accelerate commercialization. Demonstration and R&D projects alone do not accelerate the commercialization of new technologies. In fact, large, one-time purchases tend to dry up supply (and thereby increase price) without stimulating the increase in production capacity necessary for manufacturing cost reductions. Furthermore, manufacturers do not rely upon short term subsidies, mandated purchases, or set-asides in making investment decisions because these programs create "false markets." A combination of aggressive price reductions and commitments for substantial and sustained capacity acquisition is required for full commercialization of these technologies. Sustained orderly development and economies of volume for solar electric systems will result in the rapid development of a mature, costeffective solar industry.

3.2 **Commercialization Path LifeCycle Costing**

Technology development (or commercialization path) lifecycle costing, and not just "project" lifecycling costing, needs to be used. It is important to analyze total expenditures and total acquired capacity over the entire commercialization path. Higher costs for early applications can be a good investment if they contribute to accelerating the trend towards lower costs and higher performance. When solar investments are selected carefully and in collaboration with other stakeholders in renewable energy development, they can be among the wisest and, ultimately, the lowest risk investment that can be made, despite their higher initial capital costs.

3.3 **Proactive Leadership to Stimulate Early Adoption**

Sustained orderly development and accelerated commercialization will not occur early relying just on natural market forces. Accelerated commercialization will not occur just by demonstration projects and watching the cost curve. Utilities and other potential bulk purchasers must commit to an early and sustained series of substantial buys to permit the industry to invest in expanded production and automation. The "diffusion model" of PV commercialization where high value applications are identified and filled, then the next value level developed is an important starting point. It does not, however, result in a sufficient aggregation of order commitments to allow the needed expansion of production. The utility grid-connected market needs to foster accelerated commercialization with multiyear commitments for substantial and continuing, multimegawatt per year purchases.

While these early increments of PV may not be cost effective on their own, they represent a beginning of a cost effective process. Support by the other stakeholders in the process, especially by other utilities, the regulators and a reliable DOE shared risk is required on a sustained, multi-year basis to close the early cost-value gap and make the process work. This support, can not be on a year-to-year, stop and go basis. It must be match the multi-year commitment that the utility industry is making. The utility community has taken the responsibility to get this process underway now and to work with regulators, customers and other stakeholders to make it successful. The national Utility PV Group (UPVG, now up to 90 utility members) has implemented the first projects under TEAM-UP. Project TEAM-UP, provides the initial part of a sustained, orderly development process with a target of 50 MW of utility PV purchases over a four year period. Under this proposal the USDOE would provide only about 30% of the estimated $513 million program. As Andrew Vesey, Chairman of the UPVG Board of Directors and Vice President of Niagara Mohawk Power Corporation stated:

While TEAM-UP's partners may greatly help to underwrite today's "cost gap", only the federal government can close it. Critically, this federal support must also be ***sustained****. Funding assurance is essential for gaining market and supplier commitments, gearing up and implementing the program, verifying the march down the cost curve, and establishing the federal government as a reliable partner throughout the entire commercialization process.*

The successful, accelerated commercialization of utility PV applications will need to be a collaborative effort of many participants. Utilities, State and Federal agencies and other stakeholders must join together. If manufacturers do not continue to respond with aggressive forward pricing, if utilities do

utilities, such as SMUD, can achieve some initial reductions of price, the needed cost reductions for commercialization will require a much broader effort. The level of response to the 1995 TEAM-UP program is indicative that this level of commercialization can be maintained given only modest - but sustained - DOE shared-risk. These efforts, supported by all the stakeholders in the PV commercialization process, will be necessary if PVs are to achieve the cost reductions needed to meet our needs in a reasonable time-frame.

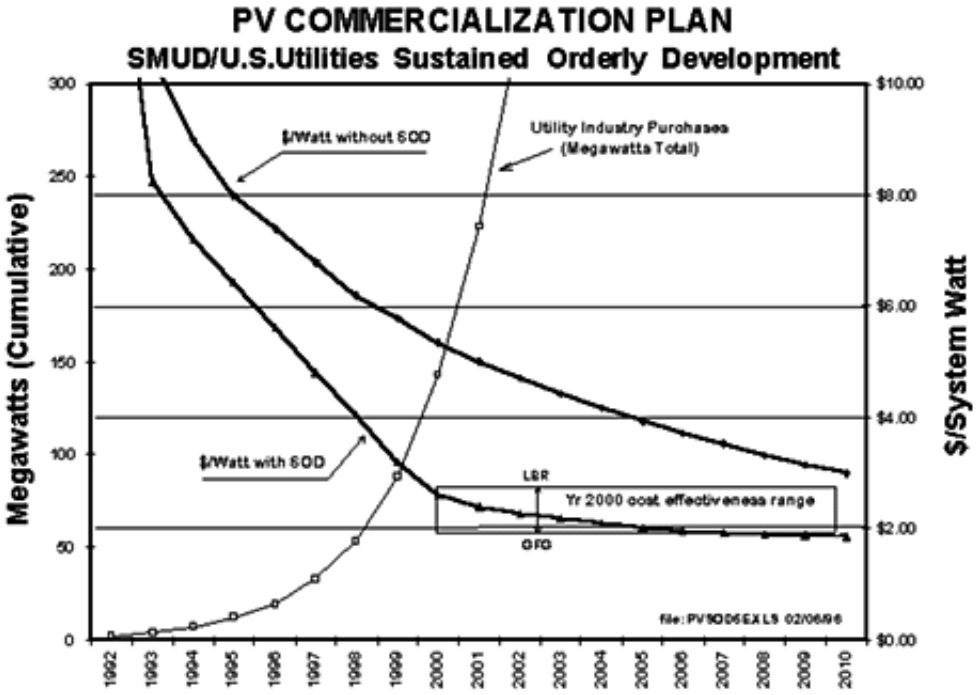


Figure 7. SMUD PV SOD Commercialization Cost-curve

Sustained Orderly Development (SOD) assumes fully implemented, sustained TEAM-UP commercialization effort.

Prices ($/W) are Turn-key system prices up to meter, AC, PTC, 30 year life. Includes installation and tax. Does not include Utility Add-on Costs. Real 1994 $.

Year 2000 Cost-effectiveness range based on: SMUD Gas Fired Generation (GFG) to Lower Bound Renewables (LBR) Year 2000 costs. Fixed, Rooftop PV systems. Tracking systems adjusted by Energy Production Factor (EPF). Turn-key system prices (total project cost less Utility Add-on Costs). Does not include non-traditional benefits such as Distributed Benefits.

5. **SMUD'S CONTINUING SOD PV PROGRAM**

During 1996, the District will continue its efforts to accelerate the commercialization of grid-connected PV applications and to define and compare the relative costs and benefits of the various models of utility PV applications including the issues of systems ownership, shared risk and benefits, levels of T&D benefits and the general issue of the appropriate accounting for all the value of distributed generation. This information will be used to update the analysis of PV benefit/cost as part of the integrated planning process.

In Spring 1996, SMUD will release its multi-year Request for Proposals for Renewables (RFP4R). This

not implement substantial, sustained purchases, if DOE does not provide a reliable and predictable multi-year costshare absorbing a part of the early risk and if other stakeholders do not proactively support the commercialization process, this process won't succeed.

4. **PV COMMERCIALIZATION COST CURVE**

Photovoltaics (PV) offer many advantages as distributed generation systems, both as a supply side option and as a demand-side management (DSM) option. PV's are the most modular and operationally simple of the clean, distributed power technologies. From 1972 to early 1992, PV module costs have been reduced 100-fold. Already PV is a cost-effective resource for a wide variety of remote and grid-independent applications. The strategic, competitive advantages of PVs will continue to increase as this cost trend continues.

Despite tremendous price decreases, PV is still too costly for most grid-connected applications. In addition, cost-effective storage and the related problem of intermittency of the solar generated electricity continue to limit PV utility applications.

Significant RD&D efforts are underway nationally to develop more efficient batteries and other electricity storage methods that will help to resolve the storage and intermittency problems. The problem of cost is being attacked on several fronts. New PV materials and designs are being developed to improve efficiency and reduce manufacturing costs and niche markets are being developed and exploited to continue the initial phases of commercialization. Indeed, the current level of production capability is all but sold out for remote applications, consumer devices and third world applications.

To achieve the next series of price reductions, firm utility scale markets must be generated and sustained to encourage the investments needed in new technology and production. Utilities can play a leading role in accelerating the further commercialization of PVs through assisting the development of utility PV markets. This effort can reap benefits for our customers by the resulting improvements in PV systems, distributed generation support to our system and accelerated reductions in PV costs.

Residential "rooftop" systems in the 2 to 4 kW range were costing about $15/W installed in 1992. Substation applications were costing about $10/W. The SMUD 1993 PV projects cost about $7.70/W and for the 1994 PV projects averaged about $6.44/W with a low of $6.10/W. The 1995 projects, despite constrained PV module supplies, have continued tracking down the accelerated commercialization cost curve with prices as low as $5.71. With a sustained, widespread collaborative effort, one could expect prices to drop below $3/W by about the turn of the century. Figure 7 summarizes SMUD's analysis of the TEAM-UP commercialization plan. It shows the expected results of a sustained orderly development process on the utility PV market based on a number of market studies by the PV industry, analysis by SMUD, UPVG and others and from sources from DOE and the national labs.

In 1993 SMUD implemented its commitment to a sustained orderly development effort starting with the 640 kW of grid-connected utility PV systems and a 5 year program of yearly PV Pioneer and T&D buys. This 5 year program leads to a 5 year period starting in 1998 where SMUD will purchase about 10 MW per year of renewable energy resources including PV. It is expected that this multi-year effort would involve the establishment of a new PV manufacturing facility with part of it's production dedicated to the multi-year, multi-megawatt utility commitment. This is especially important since it is generally agreed that "ramping up" to commercial scale PV production for utility applications cannot be at few kilowatts at a time, but rather in annual sales in the multi-megawatt range. These orders need to have continuity and be steadily increasing. Early utility industry orders and PV production increases need to be in the range of 2-5 MW/year, and they must quickly (within 2-3 years) reach 10 MW/year and 50-100 MW/year nationwide by the end of this decade. While the efforts of a few

RFP4R plans to obtain 50 MW of renewable energy resource over a 5 year period, 1998 -2002. As part of this solicitation, a 10 MW PV set-aside has been included. Proposals are expected that will provide for PV systems that will continue the SMUD PV Program, meet or exceed the cost goals indicated by the cost curve in figure 7 and result in significant PV and PV related manufacturing and jobs in the Sacramento region. Proposals are expected to be due to SMUD in the summer of 1996 and SMUD expects to sign contracts in early 1997.

6. **COLLABORATIVE PV COMMERCIALIZATION**

To succeed in accelerating the commercialization of grid-connected utility PV applications, the commercialization process must truly be a collaborative effort. The PV industry needs to nurture the grid-connected, utility market. They need to aggressively forward price to foster this developing market and to enable utilities to field systems. They need to look at investing in this market development now to create a profitable market for the future. Utilities need to proactively assist in developing a substantial, growing and sustainable grid-connected utility PV market. They need to aggressively account for the non-traditional benefits of distributed PV generation and maximize what they can afford to invest in early systems to accelerate the cost reduction and commercialization of grid-connected PV. Regulators need to recognize that the long term best interests of the ratepayer will be served by permitting and encouraging modest early investments in higher cost PV today when these investments will lead to earlier and greater cost reductions of PV for the future. They need to account for societal and economic development benefits and the benefit of commercializing a source of "green and inflation-proof" energy. The Federal government needs to share the risk by helping to fill the cost-value gap, a gap declining as commercialization moves forward, between how high utilities and regulators can value PV benefits and how low the PV industry can forward price grid-connected PV systems. The Federal government must show that it can be a reliable, sustained partner and not jerk support up and down as the winds of the political moment shift back and forth.

Each party needs to analyze their investment for a "commercialization-path" life cycle cost rather than a project-by-project basis. This process must be developed as a sustainable, orderly development of the market in a way that the PV industry can invest with confidence in new processes and manufacturing lines to lower costs and that utilities and their regulators can see accelerated and continuous progress to cost-effectiveness.

Efforts such as the Utility PhotoVoltaic Group's Project TEAM-UP with the USDOE and the PV4U collaborative state working groups offer the framework to make this collaborative commercialization of the grid-connected, utility PV market succeed.

As was stated in Time Magazine of October 18, 1993:

Some of the biggest boosters of solar power are bound to be utility companies, eager for a clean source of electricity that will enable them to produce more power without new billion-dollar plants. Both as consumers of solar technology and as the promoters of home solar panels, utilities will drive much of the industry's growth into the next century. "Utilities are beginning to realize that they're going to have to get on the solar bandwagon, says S. David Freeman, (former) general manager of the Sacramento Municipal Utility District (SMUD). "If they don't and rates go up sharply, people are going to buy their own solar panels and pull the plug on the utilities." ... "Solar is competitive now if you take the long view. And it's going to be highly competitive by the end of the decade."

The use of solar energy has many benefits to utilities, the our local communities and the country in general. Solar technology reduces the use of non-renewable resources. It is a renewable and sustainable energy source and helps improve air quality. PV power generation systems are clean, quiet and environmentally beneficial. They use no fuel and have no emissions. Each MW of PV power generated by a plant with a 25% capacity factor, will eliminate the production of more than 20,000

tons of carbon dioxide and more than 25 tons of NOx during its life as compared to the cleanest fossil fuel plants available for purchase today. Solar electric systems stimulate economic development and employment opportunities to a much greater extent than conventional energy sources. They represent a source of diversified, inflation-proof energy. For all these reasons, PV represents an energy supply that utility customers are demanding. The question is, do we have the national will to make a modest but sustained commitment to the investment in our future that will make this a cost-effective and substantial part of our national energy mix in the timeframe that we need.

National Solar Energy Conference, ASES Solar 96,
Asheville, NC, April 1996

Questions? Contact the Green Power Webmaster

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