Sacramento Municipal Utility District Solar Photovoltaic Program

Profile #111

Executive Summary

Sacramento Municipal Utility District (SMUD) is unparalleled in its commitment to renewable energy – particularly solar – as well as comprehensive energy efficiency and load management programs. (See Profiles #13,66,83,91) Through its dedication to the development of solar energy as a business strategy, and in collaboration with a number of research and marketing organizations such as UPVG, PV4U, and PVUSA, SMUD has implemented a range of solar technologies to procure resources, to build local expertise and product availability, to educate Sacramento's citizens, to support peak power generation, and fundamentally to stimulate an important market transformation whereby solar technologies become commercially viable.

SMUD's solar programs encompass a number of applications ranging from the world-renowned and record-sized PV1 and PV2 projects (fully 2 MW of arrays located at its retired Rancho Seco nuclear power plant), to its rooftop solar initiatives in the residential and commercial sectors. SMUD has also installed nearly 600 kW of PV arrays at its Hedge substation where it has developed a highly cost effective single-axis mounting strategy while exploring the economics of substation-interfaced capacity. SMUD also built the West's first public solar PV electric vehicle recharging stations.

The Solar Photovoltaics (PV) Program offers an insight into SMUD's corporate philosophy regarding its role in PV commercialization as well as a range of experiences and lessons learned. PV Pioneers, for example, involves the installation of 4 kW PV panels on customers' roofs. SMUD has found that customers are eager to pay a premium for the satisfaction of generating clean, renewable electricity! So far over 240 systems have been installed in Sacramento's residential neighborhoods allowing the utility to gain valuable insights about the distributed utility concept whereby customers also become generators, feeding small increments of power into the fingers of the distribution network where it is often needed most. SMUD has extended the PV Pioneers concept to the commercial sector and recently installed an impressive array on a quite prominent church roof in town!

One of the remarkable aspects of the Solar PV program is the level of community support that it has received and cultivated. Market research commissioned by SMUD in 1993 found that fully 26% of its customers were willing to pay a premium for PV power generated on their rooftops. Fully 70% were willing to participate in a "green pricing" program in which they would pay more on their monthly utility bills so that SMUD could establish a "Clean Energy" program. This support, coupled with the remarkable responsiveness of local contractors to refine their solar expertise, has paved the way for SMUD's solar commitment.

SACRAMENTO MUNICIPAL UTILITY DISTRICT
Solar Photovoltaics Program

Sector: *Residential, Commercial*

Measures: *Variety of systems; fixed and single-axis; rooftop initiatives and centralized installations; projects include electric vehicle recharging station, mobile demonstrations, and remote power applications*

Mechanism: *Leadership role in state and national utility photovoltaic commercialization efforts leveraging internal funds through external collaborations*

History: *World's largest PV installation in 1986; Board approves Solar Utility concept in 1992; PV Pioneers (the rooftop program) initiated in 1993*

1994 PROGRAM DATA

Energy contribution:	*1,792 MWh*
Capacity contribution:	*933 kW*
Cumulative contribution:	*20,049 MWh*
Cost:	*$5.9 million*

CUMULATIVE DATA

Energy contribution:	*7,524 MWh*
Cumulative contribution:	*63,971 MWh*
Capacity contribution:	*3.7 MW*
Costs:	*$16.3 million*

CONVENTIONS

For the entire 1994 profile series all dollar values have been adjusted to 1990 U.S. dollar levels unless otherwise specified. Inflation and exchange rates were derived from the U.S. Department of Labor's Consumer Price Index and the U.S. Federal Reserve's foreign exchange rates.

The Results Center uses three conventions for presenting program savings. ANNUAL SAVINGS refer to the annualized value of increments of energy and capacity installed in a given year, or what might be best described as the first full-year effect of the measures installed in a given year. CUMULATIVE SAVINGS represent the savings in a given year for all measures installed to date. LIFECYCLE SAVINGS are calculated by multiplying the annual savings by the assumed average measure lifetime. CAUTION: cumulative and lifecycle savings are theoretical values that usually represent only the technical measure lifetimes and are not adjusted for attrition unless specifically stated.

Sacramento Municipal Utility District (SMUD) began operations on December 31, 1946. Its service territory encompasses 900 square miles within and around the City of Sacramento, the capital of California, located in the state's central valley on a trajectory between San Francisco and Lake Tahoe. SMUD is the fifth largest municipal utility in the United States in terms of energy sales. Its 2,369 employees served 475,090 customers in 1994.[R#21]

SMUD is an independent agency governed by a five-member Board of Directors with members elected by the public for staggered four-year terms. (In 1995 the Board will expand to seven members.) There is no formal connection between SMUD and city or county government or any other local government agencies. Its Board is responsible for setting rates, establishing District policy, and appointing the General Manager, who in turn is responsible for utility operations and hiring staff.

Given the hot, dry climate that marks Sacramento's summers, and its mild winters, it's not surprising that SMUD is a summer peaking utility. In 1994 the utility experienced a peak demand of 2,052 MW after its load management programs were dispatched. Between purchased power and utility-owned power, SMUD had a peak generating capacity of 2,162 MW creating a reserve margin of 5.4%. In 1994, the utility had customer electricity sales of 8,460 GWh.[R#21]

In 1994, SMUD's electricity generation was primarily derived from purchases which comprise 7,877 GWh, or 86%, of the total power supply. The closure of SMUD's Rancho Seco nuclear power plant in 1990 that had supplied 2,812 GWh in 1988 and 1,439 GWh in 1989 forced the utility to increase the use of purchased power. Even prior to Rancho Seco's closure, SMUD had been forced to dramatically increase its use of purchased power because of repeated problems at the nuclear plant. The remainder of SMUD's power in 1994 came from hydroelectric sources (738 GWh or 8%), geothermal resources (332 GWh or 4%), gas turbines (11.3 GWh or <1%), and photovoltaics (2.5 GWh or <1%).[R#21,22]

SMUD 1994 ELECTRIC STATISTICS

Number of Customers	*475,090*
Number of Employees	*2,369*
Energy Sales	*8,460 GWh*
Energy Sales Revenues	*$588.2 million*
Peak Demand	*2,052 MW*
Generating Capacity	*2,162 MW*
Reserve Margin	*5.4%*
Average Electric Rates	
Residential	*7.31 ¢/kWh*
Commercial and Industrial	*6.72 ¢/kWh*

California has been in a severe recession for the past several years, in large part because of the decline of the aerospace and defense industry. During 1992, the total population of Sacramento decreased for the first time ever, and SMUD had 1,494 fewer customers at year end 1993 than year end 1992. This trend is now changing. In 1994, SMUD's customer base grew by over 8,000, a 1.8% increase.[R#21,22]

SMUD has not raised its electric rates since January 1990. Residential customers pay an average of 7.31 ¢/kWh, while commercial and industrial and all other customers pay 6.72 ¢/kWh, making the utility's rates among the lowest in the state. Nevertheless, rates are a major issue at SMUD because the utility believes it is essential to keep its rates substantially below PG&E's for competitive purposes.

Utility DSM Overview

Sacramento Municipal Utility District began its energy efficiency efforts in 1976 with the creation of a Conservation Department. Initially this department focused on customer education and basic residential efficiency measures such as attic insulation retrofits, rebates for energy-efficient construction, and a test of direct load control for air conditioners. These efforts were expanded in the early 1980s in part as a response to state and federal mandates such as the California Energy Commission's (CEC) Load Management Standards and the U.S. Department of Energy's (DOE) Residential Conservation Service program.[R#23]

1993 SMUD DSM PROGRAMS

Residential Retrofit
Direct Investment
Community Partners
Retail Lighting
Shade Trees
Solar Domestic Water Heating

Load Management
Residential Peak Corps
Commercial Peak Corps
Water Pump Load Management
C/I Load Management: Auxiliary Power, Curtailable Service, Fast Dispatch
Pool & Spa

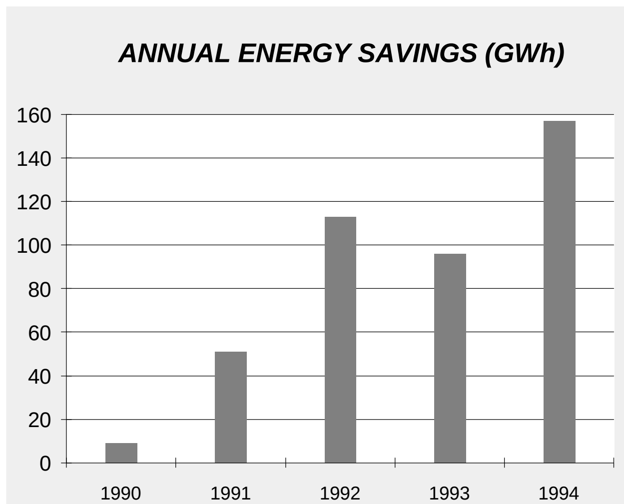
Equipment Efficiency
Energy Efficient Refrigerators
Residential Equipment Efficiency Improvement
C/I Equipment Efficiency Improvement

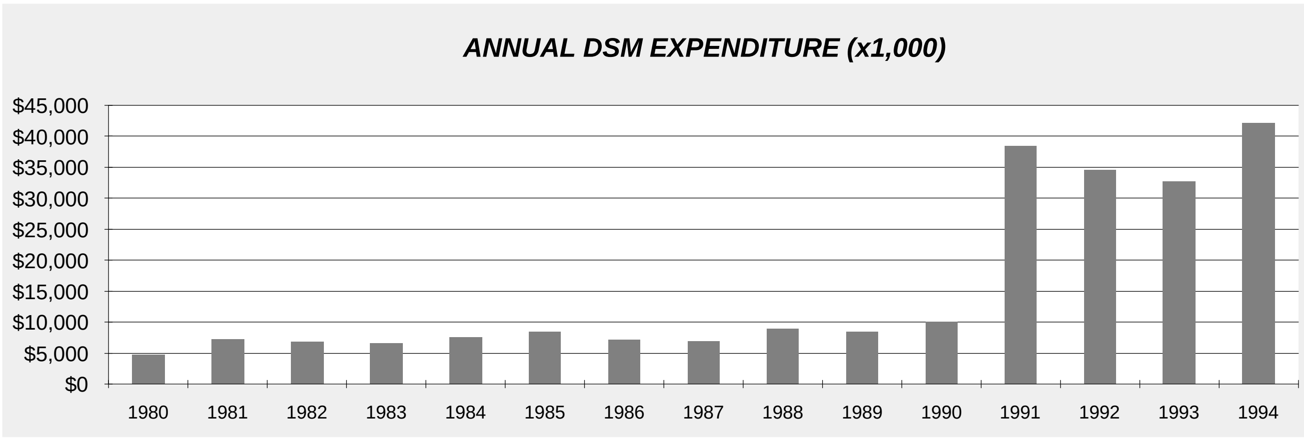
Commercial / Industrial Retrofit
Small C/I Retrofit
Large C/I Retrofit
DSM Bid
Schools & Public Buildings
Multi-Family Retrofit

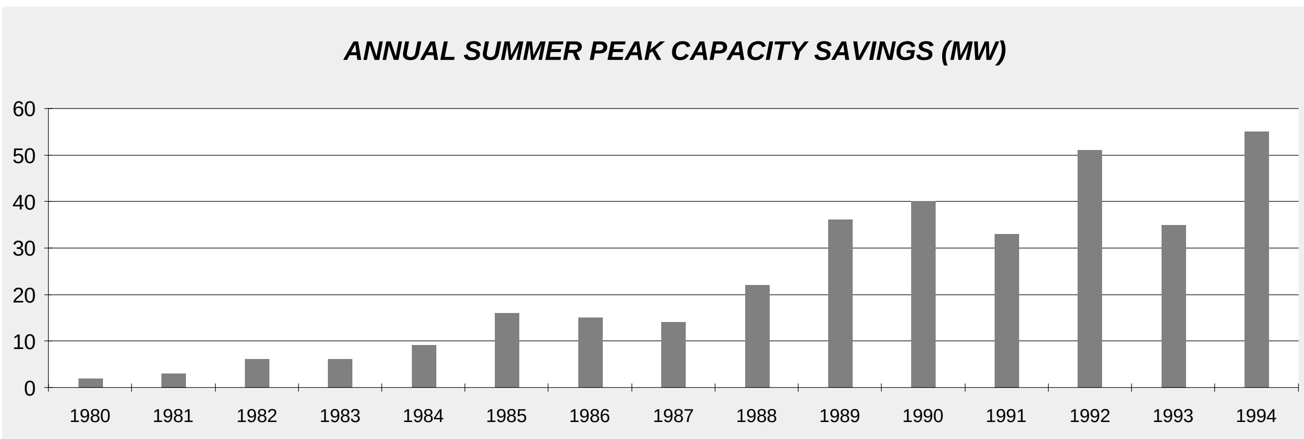
New Construction
Residential New Construction
Commercial / Industrial New Construction
Residential Thermal Energy Storage
Commercial Thermal Energy Storage

Education
Total School Energy Management

DSM OVERVIEW	DSM EXPENDITURE (x1,000)	ENERGY SAVINGS (GWh)	PEAK CAPACITY SAVINGS (MW)
1978	$3,608	Negligible	13
1979	$4,501	"	1
1980	$4,758	"	2
1981	$7,189	"	3
1982	$6,772	"	6
1983	$6,561	"	6
1984	$7,548	"	9
1985	$8,503	"	16
1986	$7,155	"	15
1987	$6,903	"	14
1988	$8,839	"	22
1989	$8,432	"	36
1990	$10,000	9	40
1991	$38,317	51	33
1992	$34,562	113	51
1993	$32,717	96	35
1994	$42,100	157	55
Total	$238,465	426	357







In response to significant needle peaks resulting from air conditioning load, SMUD developed and adopted the Load Management Business Plan in 1987. Implementation of this plan improved the utility's load management programs with a continued focus on residential air conditioning units and new attention to commercial and industrial curtailable efforts, thermal energy storage incentives, and time of use rates.[R#23]

During the late 1980s the citizens of Sacramento elected three Board members (and thus a majority) who strongly favored conservation. What really catalyzed the Board's direction, however, was the series of events that resulted in the closure of the Rancho Seco nuclear plant. The plant (or "the ranch" as it was called) was closed for slightly more than two years after its fifth significant cooling accident in December 1985. As a result of this outage, SMUD undertook an extensive program of upgrades to plant and personnel to improve the plant's reliability and availability. Plant costs spiralled and utility rates went up. A community action group placed an initiative on the local ballot during this period to close the Rancho Seco plant immediately and permanently. The SMUD Board countered with a referendum to operate the plant for 18 months and then decided its fate based on the level of operation achieved during that period. The community initiative failed, while the Board's initiative passed. The plant was restarted in March 1988 but continued to suffer breakdowns. A second referendum, permitting continued operation of the plant, was rejected by voters in June 1989 and SMUD was forced to retire the plant.[R#25]

In January 1990, the Board set forth the goal to make energy efficiency the District's priority resource as a result of the premature closure of the Rancho Seco nuclear power plant (913 MW) and a changing corporate vision of the utility's role as a provider of energy. To fulfill this mission, the Board selected S. David Freeman as General Manager. By this point in his career, David Freeman had developed a strong reputation as an outspoken advocate of public power in his previous positions at the helm of the Tennessee Valley Authority and the Salt River Project. Freeman was charged with promoting integrated resource planning (IRP), demand-side management (DSM), and renewable technologies at SMUD and to thus chart a new course for the demoralized utility.[R#25]

SMUD developed an energy efficiency goal of 800 MW from what it calls its "Conservation Power Plant," and 400 MW from renewable and advanced energy projects by the year 2000. Savings were identified in three major areas: Energy Efficiency Retrofit, New Construction, and Load Management. The utility then began design and implementation of various programs in these areas.

All facets of SMUD's DSM activities followed suit. During 1990 and 1991 the Energy Efficiency Department grew from 80 to 240 staff members. Prior to David Freeman's arrival DSM was generally considered a customer service. After his arrival it was more fully integrated as a resource with Energy Efficiency staff being fully integrated into the organization. SMUD's expenditures on DSM since 1990 have reflected its aggressive portfolio of programs. For instance, while the industry-wide average for DSM spending as a percentage of gross revenues was 1.2% in 1992, SMUD's 1993 DSM expenditures were 5.55%, one of the largest in the United States. In 1994, SMUD spent $42.1 (levelized 1990$) million on demand-side management and conservation initiatives.[R#1,5]

Most of the utility's programs target both capacity and energy savings, with the obvious exception of the load management programs. This focus is in direct contrast with SMUD's efforts prior to 1990 that were almost exclusively capacity oriented. As the charts on the previous pages show, energy savings from DSM efforts are negligible until 1990.

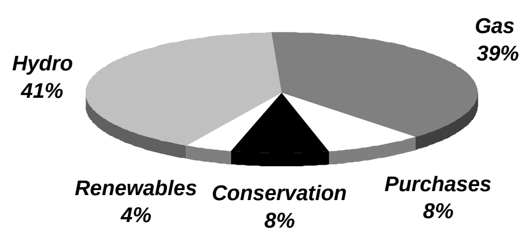
The current portfolio of programs, however, is providing substantial energy and capacity savings: a total of 96 GWh and 35 MW in 1993. In 1994, energy and demand savings increased drastically: 55 MW in demand (a 57% increase over 1993), and 157 GWh (a 63% increase). Since the inception of energy efficiency programs at SMUD, over 426 GWh of electricity consumption and 357 MW of capacity savings had accrued by the end of 1994.[R#4]

One of SMUD's most intriguing programs is its Solar Domestic Hot Water (SDHW) program (see The Results Center Profile #66). SMUD calculated that SDHW systems could provide substantial energy and capacity benefits to the utility by replacing existing electric water heating. The utility decided to design and implement a program that would capture these energy benefits while lowering the costs of systems and improving the SDHW market. To date more than 3,000 solar hot water systems have been installed on rooftops throughout Sacramento.[R#9]

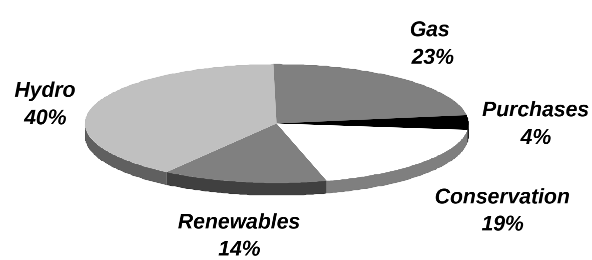
Through 1993 SMUD has had over 62,100 refrigerator trade-ins, performed 26,865 residential energy audits, paid $31.47 million in rebates to ratepayers, planted 112,600 shade trees, and acquired over 96,100 participants in their Residential Peak Corp program (See Results Center Profile #83 for details).

SMUD continues to refine its DSM activities to further diversify its resource mix and to expand the rate of conservation and renwables, while decreasing gas usage. The utility underwent a review by the Natural Resources Defense Council and the Conservation Law Foundation during 1992. This review resulted in recommendations that SMUD adopted to refine their cost-effectiveness screen. This helped SMUD account for the benefits of reducing peak demand, implement direct-installation programs for residential customers to improve participation, encourage retrofits at the time of replacement, and expand and intensify evaluation efforts.[R#4]

EXISTING RESOURCE MIX



PROPOSED RESOURCE MIX



HOW DO PVS GENERATE ELECTRICITY?

Photovoltaics (PVs) are an exciting means to directly convert sunlight into electricity. The fuel for PVs, sunlight, is free and abundant. In the U.S. the total sunlight received in a year is about 24 billion GWh, more than 10,000 times our annual use of electricity.

PVs generate electricity via the photovoltaic effect, which is the ability to generate electricity directly from sunlight. This is done through the use of semiconductors in a manner somewhat similar to the operation of transistors.

Light energy (whether it be from the sun or some artificial lighting source) consists of a stream of energy called photons. It is this stream of photons which strikes the solar cell and generates an electron flow within the PV cell.[R#3]

Almost all PV cells are made of crystals of silicon, one of the most common elements on earth, one of the primary elements found in sand. The pure silicon used in making solar cells is a semiconductor containing few free electrons. (It is the free electrons in a material which enable it to conduct electricity).[R#3]

By itself, silicon is not a very good electrical conductor. But when the silicon is doped with other elements, usually phosphorus, which can lend a free electron, a compound which has extra electrons results, yielding a net negative charge. When boron is added, each boron atom adds one hole to the compound, a place in the atomic structure where an electron should be, but isn't, yielding a net positive charge.

In making PV cells, large crystals of silicon (containing a small amount of boron) are grown in a special laboratory condition in a vacuum, while heated. These crystals are then cut into extremely thin wafers. A coating of phosphorus is then added to the top of these wafers.[R#3,17]

When light energy passes into the cell, opposing positive and negative charges are set up in the cell. The cell has been put together so that current can only flow one way, from the negative to the positive semiconductor. By connecting wires to each side of the wafer, this current which is caused by light energy, can be used in electrical circuits.[R#3,4]

A group of cells comprise a module and a group of modules comprise an array. When arrays are placed together, they make up a system, which is typically composed of the PV panels and the balance-of-system (BOS). The BOS is composed of the panel supporting structure, wiring, controls and a power conditioning sub-system with an invertor. The invertor converts the DC output from the PV panels to AC power. Systems may also include batteries for energy storage.[R#4,17]

There are three broad categories of solar PVs:

- crystalline silicon flat plates (both single crystal and polycrystalline silicon);
- thin film flat plates (including amorphous silicon and polycrystalline cadmium telluride);
- concentrators (including silicon, gallium arsenide, and a variety of multijunction approaches);

These categories allow a choice of efficiencies from 10-35% to be utilized in cost-effective configurations. [R#3,17]

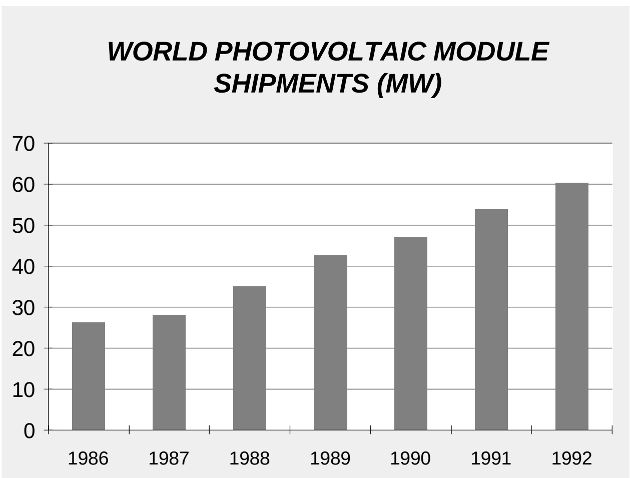
NATIONAL AND WORLDWIDE USAGE OF PHOTOVOLTAICS

Substantial progress in improving the performance and lowering the cost of PV generated electricity has occurred over the past fifteen years in spite of the fact that federal funding in research and development for most of this period has declined dramatically. The solar industry has now produced crystalline silicon cells with efficiencies as high as 23%. Advanced PV devices with 35% efficiency under highly concentrated sunlight have been demonstrated.

Since 1972, PV module costs have been reduced 100-fold to as low as $4/watt. Today's PV systems can produce power at about 18-20 ¢/kWh. While costs of PV systems vary with application, the grid-connected PV systems SMUD installed in 1994 range from about $6.00 to $6.50/watt. The DOE's goal for the end of the decade is 5-6 ¢/kWh. PVs are currently cost-effective for many dispersed applications as an alternative to utility power line extensions. An example of this includes remote water pumping (See Profile #29: Western Area Power Administration, Solar DSM). As PV costs continue to decrease, cost-effective markets expand.

Photovoltaics offer unique opportunities because of their extreme modularity and flexibility. PVs can be applied over a wide range of power levels, from small remote and distributed residential DSM applications, to mid-size grid-supported commercial applications, to centralized power stations.

Of greater near-term interest are the generation applications of PVs where benefits beyond the energy and capacity savings can be realized to justify the early high cost of PV electricity. PV's clean and quiet operation adds to the high degree of siting flexibility. PVs in distributed applications can reduce the need for transmission and distribution improvements, increase reliability, and provide demand-side management (DSM) opportunities. The short construction time for PV systems can allow incremental additions to power systems and reduce planning risk. SMUD is determining methods to capture these distributed benefits.



THE WORLDWIDE MARKET

In order to produce one percent of the world's electricity capacity using solar energy, 1,500 MW of capacity would have to be added each year for the next 10 years. With a current world market of 60 MW per year, it is apparent that in order to reach that goal, solar initiatives must be greatly expanded. However, national and worldwide markets in PVs are increasing significantly each year.[R#3,10]

World PV module shipments have more than doubled in only seven years, rising from 26 MW in 1986 to over 60 MW in 1992. Clearly, the technology is moving vigorously into the international marketplace at a very rapid rate. Of greater significance for the future, a minimum of 150 MW of new PV module production capacity is on the drawing boards for the next five years. This new capacity is almost three times greater than total worldwide output in 1991.[R#8,15]

The total value of photovoltaic cell and module shipments was $110 million in 1993, a 26% increase over the 1992 value of $87 million. The average price of crystalline silicon modules in 1993 was $5.11 per peak watt, a decrease of 16% from the 1992 price of $6.10. The average price for thin-film modules was $7.64 per peak watt, 21% higher than 1992 prices.[R#8,10,15]

WORLD PHOTOVOLTAIC MODULE SHIPMENTS IN MW	1986	1987	1988	1989	1990	1991	1992
United States	8.7	9.3	12.4	15.5	15.7	16.2	18.4
Japan	11.5	12	11.7	12.7	15	18.7	18.8
Europe	4.2	4.3	6.4	8.7	10.5	13	17
All Other	1.7	2.4	4.5	5.7	5.7	6	6
Total	26.1	28	35	42.6	46.9	53.9	60.2

THE NATIONAL MARKET

In 1993, U.S. shipments of photovoltaic cells and modules totaled 21 peak megawatts from 19 different companies, a 14% increase over 1992 and roughly 33% of world production. Since 1988, shipments of photovoltaic cells and modules have increased at an average annual rate of 17%. The value of these shipments has increased from $87 million in 1992 to $110 million in 1993, a 26% increase.[R#8,15]

In the United States the largest end-use application of PV cells and modules in 1993 was for electricity generation, representing 33% of total shipments and 6.8 peak megawatts. The second largest PV end-use in 1993 was in the transportation sector, which accounted for 4.2 peak megawatts. PV units used to power fixed-based communications equipment, such as mountain-top signal repeater stations, totalled 3.8 peak megawatts, or 18% of total shipments, and water pumping end-uses accounted for 2.3 peak megawatts.[R#8,10,15]

The industrial sector was the largest market for PV cells and modules in 1993, accounting for 26% of total shipments. In this market, PV cells and modules are used to produce power for industrial applications such as line switching, remote telecommunications, microwave repeaters, railroad switch signals, or to mitigate corrosion of gas pipelines. Use of cells and modules in grid-connected and remote PV systems to provide power for the residential sector was the second largest market for PV in 1993, and accounted for 25% of total shipments. The commercial market was the third largest PV market, accounting for 20% of total shipments in 1993. Commercial market sector cells and modules were shipped to provide power for commercial establishments such as office buildings, retail establishments, private hospitals, and schools. The transportation sector accounted for 12% of total shipments in 1993.[R#8,10,15]

PVUSA

The Photovoltaics for Utility Scale Applications (PVUSA) initiative, based near Davis, California, is a cooperative effort of Pacific Gas & Electric (PG&E), Electric Power Research Institute (EPRI), the U.S. Department of Energy (USDOE) and other utilities including SMUD, intended to specify, purchase, test and report on available photovoltaic systems suitable for installation by utilities.

PVUSA has a program in which a utility hosts a PV project. If the hosted project is chosen from the ones packaged by PVUSA, then the one time cost of $200,000 to join and become a member of the Steering Committee and Technical Advisory Committee is waived.

PVUSA helps develop solar PV project proposals and its members are able to utilize technical and bid development information that enhances bidding capability for utility PV systems. In addition, the testing at PVUSA supports the SMUD PV program since they are currently testing emergent modules on a utility scale.[R#16] ☞

For additional information contact: PVUSA Project Office, 2303 Camino Ramon, Suite 200, San Ramon, CA 94583, Phone: 510-866-5569

THE UTILITY PHOTOVOLTAIC GROUP (UPVG)

Created in September of 1992 through a collaborative effort and funding by the Electric Power Research Institute and the U.S. Department of Energy, the Utility Photovoltaic Group (UPVG) is a consortium of utilities whose purpose is to accelerate the use of cost-effective small-scale and emerging large-scale commercial applications of PVs for the benefit of electric utilities and their customers. SMUD is a founding member with S. David Freeman serving as an original UPVG Director. SMUD's Solar Program Director, Donald E. Osborn, now serves on the UPVG Board of Directors.[R#11]

UPVG is organized to assist in addressing the major issues and barriers to accelerated utility application of PVs. It helps resolve regulatory concerns that reduce investor-owned utilities' vigorous development and commercialization of PVs. UPVG is led and managed by the market itself – the potential utility buyers of solar photovoltaic systems.

By the Spring of 1993, 65 utilities had formally joined UPVG. Currently, UPVG has 86 utility members representing approximately 40 percent of total U.S. kilowatt sales. Utility member dues are based on revenues with minimum dues of $1,000 per year and maximum dues of $4,000 per year.[R#11,12,13]

For additional information contact the UPVG project coordinator at: UPVG, 1800 M Street, NW, Suite 300, Washington, DC 20036-5802, Phone: 202-857-0898, fax: 202-223-5537

THE TEAM-UP INITIATIVE

TEAM-UP, which stands for Building Technology Experience to Accelerate Markets in Utility Photovoltaics, involves volume purchases of PV systems for larger-scale applications. The initiative was stimulated by the U.S. Department of Energy as a first-of-its-kind partnership between the public and private sectors to lead to earlier sustainable utility photovoltaic markets. It was then proposed by the UPVG on behalf of the utility market as a $500 million market-led program undertaken over a six year period to build a broadened base of hardware experience as an essential first step which may lead to the accelerated commercialization of PVs. The goal of the program is to competitively procure, install, and demonstrate 50 MW of PV systems. TEAM-UP support is meant to be a catalyst to individual buyer team-supplier contracts.

The Small-Scale Application portion of TEAM-UP is being implemented on a parallel path to address grid-independent installations that may be promoted and facilitated through group buyer actions. Less than one-third of the funding comes from the federal government. The rest comes from the market itself.[R#12]

For more information contact: Bethany Wills, Project Coordinator, UPVG, 1800 M Street, NW, Suite 300, Washington, DC 20036, Phone: 202-857-0898, Fax: 202-223-5537

PHOTOVOLTAICS FOR UTILITIES (PV4U)

Major barriers to the expanded utility use of PVs are cost and regulatory concerns. PV4U is a collaborative effort among the major stakeholders in PV commercialization. They include the American Public Power Association, Edison Electric Institute, Electric Power Research Institute, National Association of Regulatory Utility Commissioners, National Association of State Energy Officials, National Association of State Utility Consumer Advocates, National Rural Electric Cooperatives Association, Solar Energy Industries Association, and the U.S. Department of Energy. The California PV4U group has drafted a State PV Commercialization Strategy and is continuing to meet to expand it into an action plan. SMUD is centrally involved in these efforts.[R#13]

For more information contact: Solar Energy Industries Association at 202-383-2628

DOE PVBONUS

In late 1992, the DOE issued a request for proposals for the PVBONUS program, a 5 year, $25 million cost-shared initiative. The PVBONUS program (Building Opportunities in the US for PVs) was established to support the development of cost-effective PV products and applications in the buildings sectors. These applications include using PV arrays as architectural functions (such as glass curtain walls where the PVs can replace building components and do double duty as a building material and power generator), DSM applications, and building control functions. These approaches will significantly reduce the effective cost of PV electricity.[R#4]

For more information contact: The U.S. Department of Energy, John Thorton, NREL, 1617 Cole Blvd., Golden, CO 80401, Phone: 303-384-6469

As part of SMUD's committment to its Conservation Powerplant, the SMUD Board of Directors, by adopting Resolution 91-11-2, approved a policy to bring 400 MW of capacity online by the year 2000. This capacity is to be made possible through improvements in renewable and other advanced generation technologies implemented under the Advanced and Renewable Techologies (A&RT) program. A&RT is designed to coordinate the development of advanced generation technologies and bring about cost reductions and reliability improvements in their application. The A&RT plan covers a variety of advanced and renewable technologies including fuel cells, advanced turbine cycles, and solar electric generation systems.[R#4,12]

On October 15, 1992, the Board approved Resolution 92-10-2, which set forth the Solar Utility Concept and directed staff to develop a plan for the sustained and orderly commercialization of photovoltaic technology. Solar energy applications thus became important aspects of SMUD's renewable resource generation technologies, providing the cleanest, most efficient power plants available, independent from fossil fuel resources.

SMUD has now embarked on an ambitious commercialization effort to further expand grid-connected, utility solar photovoltaics. SMUD aims to develop the experiential base needed to successfully integrate PVs into the utility system as distributed generation and to stimulate the collaborative processes needed to accelerate the cost-reductions necessary for these PV applications.[R#4]

The purpose of the Solar Program is to develop and install cost-effective energy and capacity-reducing solar technologies by identifying and eliminating barriers to the development and implementation of solar technologies and strategies; nurturing the development of new solar technologies and the infrastructure needed to deliver them; providing informational and financial resources to the Sacramento community; acting as a catalyst for the accelerated development and deployment of solar energy systems; and becoming a solar utility, providing the means for their customers and the District to obtain the benefits of solar energy systems.

ELEMENTS OF SMUD'S SOLAR INITIATIVES:

The SMUD Solar program is organized into three elements designed to increase Sacramento's use of solar energy: 1) the Solar Domestic Hot Water program (For an in-depth look at this program see The Results Center Profile #66) 2) the Solar Buildings program, and 3) the Solar Electric program.

Solar Domestic Hot Water Element: This element uses attractive performance based rebates, financing, and strict quality assurance requirements to encourage electric water heater customers to switch to solar water heating. Through the program, solar domestic hot water systems (SDHW) offer a cost-effective alternative to electric water heating. This effort was designed to acccelerate the adoption of SDHW systems in the SMUD's service territory, to provide reliable and durable systems, to assist in the development of a mature SDHW industry, and to stimulate major reductions in the cost of SDHW systems. In two years, over 1,700 customers used this program and reduced their electric water heating energy consumption by an average of 60%, saving over 4,500 MWh and 0.64 MW of capacity. This provided SMUD with needed peak capacity and energy benefits. As of early 1995, over 3,000 SDHW systems had been installed under this program.[R#9]

Solar Buildings Element: The Solar Buildings effort provides design assistance and incentives to encourage the incorporation of cost-effective passive, as well as other solar features in the design and construction of both new buildings and the retrofit of existing buildings. The Solar Buildings program also encourages the development and implementation of solar and related, low-energy cooling systems for Sacramento. In these situations, solar energy provides a major portion of the buildings' space conditioning needs and substantially reduces peak loads.[R#4]

Solar Electric Element: The Solar Electric program element is comprised of two areas: 1) solar thermal electric (STE) systems, which include the Solar Two Central Receiver Project and the Utility-scale Solar Dish/Stirling Engine Joint Venture, and 2) photovoltaic (PV) systems (the subject of this Profile). The solar electric effort is designed to affect the near-term, cost-effective applications of PVs and STE systems, and to promote and accelerate the orderly development of solar electric technologies. [R#4,1] ☞

SMUD'S ROSTER OF PV INITIATIVES

SMUD is the leader in utility grid-connected applications of PVs. It has a number of efforts including: 1) grid-connected residential rooftop PV installation, "PV Pioneer" program; 2) a commercial building rooftop application consisting of a 40 kW, innovative concentrator PV system; 3) a single-axis tracking distribution support PV system located at a SMUD substation; 4) the world's largest operating PV power plant at 2 MW, the SMUD PV1/PV2 located at Rancho Seco; 5) the first public PV electric vehicle recharge station in the West; and 6) other initiatives which include a mobile PV demonstration system and remote power and sensor applications including a number of PV powered street lights and emergency phones.[R#4,18]

SMUD'S PV PIONEER PROGRAM

The PV Pioneer project establishes a partnership with customers willing to assist in the early adoption of PV technology. SMUD's progressiveness in the field of solar energy has made Sacramento more aware of the benefits and appropriateness of solar power, and as a result, a more willing market.

Within the program SMUD purchases, installs, and operates 4 kW residential rooftop PV systems. (Four kilowatts of power provides most of the annual energy needs of an average home.) Although SMUD owns the units and the power generated goes into the utility grid, participants volunteer to share in this effort through a form of "green pricing" and by providing the roof area. PV Pioneers pay a premium ($4-6 per month representing an average 15% bill premium) on their utility bills for the PV generated electricity. In doing so, the PV Pioneers have the satisfaction of generating clean, renewable energy on their own rooftops while SMUD gains experience in the installation, operation, maintenance, and pricing strategies for implementing residential PV systems. This joint effort is helping to advance the development of PV technology and accelerate its commercialization.[R#4,18]

The only PV program that might require marketing, the PV Pioneer program has had very little. Inserts in residential customers' monthly utility bills have been enough marketing to oversubscribe the program. The response of a limited media effort greatly exceeded expectations. Almost 2,000 customers volunteered for the first 100 slots with more than 600 passing the prequalifying screening process over the phone and agreeing to pay the 15% premium. From this pool, the first 108 PV Pioneers for 1993 were selected. In 1994, 134 systems were installed.[R#1]

The PV Pioneer selection process includes the following: customers submit an application or volunteer through a telemarket campaign; applications are pre-screened by phone; and qualified volunteer homes are visited for evaluation.

Criteria to evaluate potential customer's sites are: the roof orientation must be south to west; there must be no shading of the roof area where the PV panels will be installed; the roof material must be composition shingle; the roof size must be at least 400 square feet; and the distribution must be of geographic benefit to SMUD.[R#1,4]

The 1993 PV Pioneer systems were supplied as turn-key installed systems by Siemens Solar Industries (SSI). A 4 kW system consists of 84 SSI M55 modules configured in 12 panels. Each panel consist of 7 modules with 4 panels making up a source circuit, and three source circuits making up a standard 400 square foot array. A few systems were down-sized by one-third (to 2.66 kW) by eliminating one source circuit to accommodate roofs with less free area. Innovative Ascension Technology roofjacks permitted quick installation of the PV arrays. The complete array installation requires only 1.5 hours for the typical roof. A 4 kW Omnion invertor converts the 600 volts direct current (VDC) to single phase, 240 volts alternating current (VAC).

The 1994 PV Pioneer systems were supplied by two contractor teams for a total of 134 systems and 472 kW. Solec International, Inc. supplied 109 3.7 kW systems with Omnion invertors at a turn-key cost of $6.23/watt. The PV systems enter the utility grid by feeding their output through a separate utility meter on the utility side of residential service meter.[R#1]

COMMERCIALLY SITED PV SYSTEMS

Under the rubric of commercially sited PV systems was the installation of one 40 kW commercial building sited PV system that uses an innovative concentrating PV system, uniquely adaptable to roof-top applications. Ths sytem was installed on the SMUD-owned 59th street warehouse building. The installation is a demonstration project that provides experience in the area of grid-connected, commercial building sited generation using photovoltaics.

The system covers a 4,000 square foot area and is a roof-mounted single axis tracking, concentrating PV system with a south orientation at a 38 degree pitch. The system uses 10X concentration lenses focused on 11% efficient single crystal PV cells. An Omnion 50 kW inverter converts 720 VDC to 480 VAC. The system enters the utility side of the commercial building services meter. The system was completed in the Fall of 1994.

SMUD also plans to initiate a number of building-integrated PV projects through its commercial focus. Building-integrated PVs take advantage of potential cost savings by using the PV structure in a way that provides value beyond just electricity production. For example, they include PV structures that act as building components such as windows, roofing material, skylights, or shading devices. Building-Integrated PV systems also include PV DSM (PV systems that are designed to meet a specific high value DSM application).

The commercial roof-top systems totaling 144 kW purchased in 1994 are scheduled to be completely installed by mid 1995. These include 24 kW on a VFW Hall and 30 kW on a local church. These systems are supplied by Solec International for $6.25/watt and use the Solec module and Omnion invertors. Each 18 kW system will cover about 1,800 square feet.

THE HEDGE SUBSTATION

In 1993, SMUD installed a 210 kW ground-mount PV system at its Hedge Substation to demonstrate the ability and versatility of placing medium sized PV systems for SMUD distributed generation benefits.

This PV system is a ground mount, single-axis east-to-west solar tracking system designed, constructed, and installed by Utility Power Group. It consists of 20 identical rows configured with 240 Siemens M55 PV modules. A 250 kW Omnion invertor transforms 720 VDC to 12.47 kVAC for grid interconnection. The system serves roughly 50 households for an operating life of 50 years. The PV contract cost was $1.6 million, 20% lower than comparable utility-scale PV systems. Wooden utility poles, rather than traditional steel and concrete, were used to support the panels. Although lighter in weight, the new design allows PV panels to operate in wind speeds up to 80 mph. Most PV tracking systems shut down at half that speed.[R#1]

In 1994 SMUD installed three additional PV power stations at the Hedge site totaling an additional 317 kW. Bell Products, Inc. and Advanced Photovoltaic Systems, Inc. (APS) supplied a 108 kW system using the APS thin-film module and Kenetech invertor. Resource Management International and Solarex supplied a 102 kW system using Solarex modules and a Kenetech invertor. Utility Power Group and Siemens Solar supplied a 107 kW system using Siemens modules and UPV invertors.[R#1,4,7]

SMUD PV1/PV2

SMUD PV1 and PV2 are photovoltaic power plants located in a 20-acre field adjacent to the Rancho Seco Nuclear Generation Plant, 30 miles southeast of Sacramento. The majority of the 1,600 PV panels in service at PV1 and PV2 were manufactured by ARCO using single crystal technology. Computer-controlled motors move the panels 3 degrees every 12 minutes, starting about three hours before solar noon and ending three hours later. Rotating the panels this way produces approximately 30 percent more energy than stationary panels. The rated capacity of the PV1 plant is 1.17 MW and the PV2 plant is 1.135 MW. They were put on-line in August 1984 and March 1986 respectively and until recently the largest operating photovoltaic power plant in the world. (ENEL, the Italian national utility, recently installed an even larger system in southern Italy.)[R#1,4]

ELECTRIC VEHICLE RECHARGING STATION

On August 5, 1992, SMUD unveiled the first public solar powered electric vehicle charging station in the western United States. By utilizing advanced photovoltaic panels, energy from the sun is used to provide power for up to sixteen non-polluting electric vehicles. This bold step further underscores SMUD's commitment to cleaner air and renewable sources of energy production.

The free standing structure, measuring 8 feet by 130 feet, provides 16 shaded parking spots specifically reserved for electric vehicles. Automated rotation of the array optimizes the sun's angle, providing maximum power at all times, even on cloudy days. Peak output from the array is 12 kW. Average daily energy production is 68.4 kWh AC. The 1,000 square foot array provides enough daily energy to drive: 1 compact pickup 30 miles, 4 compact sedans 30 miles each, and 10 neighborhood EVs 25 miles each.[R#1,4]

OTHER INITIATIVES

Mobile PV Demonstration: To raise awareness of the potentials of PVs, SMUD developed a mobile PV system mounted on a small trailer for convenient transport that consists of multiple PV modules, an invertor, and balance of system including a battery for energy storage. The trailer is also equipped with high-efficiency outdoor lights, solar ovens, and a public address system. It is used for education and demonstration purposes to promote public understanding and use of PV systems.

Remote phones, switches, and street lights: Recent improvements in the efficiency and reliability of lamps, coupled with reductions in the cost of photovoltaic collectors, have significantly improved the economics of powering streetlights for remotely located applications using the sun. SMUD has installed numerous remote lighting systems powered by solar PVs. SMUD realizes that such lighting can be powered by photovoltaics at a fraction of the cost of extending utility lines in remote areas. The lamps can be controlled by timers, photocells, or sensors. Principle uses of these lighting systems are for billboards, highway signs, security lighting, public-use facilities such as parking lots, and remote homes, facilities, and vacation cabins. In a similar way, SMUD also has cost-effectively powered numerous remote emergency phones using PVs.[R#1]

SMUD has aslo exploited this opportunity for remote transmission line switches. These switches typically require a small amount of energy over the course of a year. The small photovoltaic system needed for such a load costs a fraction of the price for a transformer capable of interconnecting at transmission voltages.[R#1]

STAFFING REQUIREMENTS

Don Osborn is Supervisor and Senior Program Manager of SMUD's Solar program which includes both the thermal and photovoltaic divisions. He devotes 0.5 full time equivalents (FTEs) to the Solar PV program. Dave Collier is the Principle Electrical Engineer who manages the Solar PV program, devoting all of his time to the program. A graduate student assists Dave Collier in various capacities, devoting 0.5 FTE to the program. All told, 2.0 FTEs are devoted to the Solar PV program. Additional assistance from other departments is provided on an as-needed basis.[R#20]

MONITORING

All of SMUD's solar PV projects and programs are monitored in some form on a continuous basis. A graduate student assists Dave Collier in composing tracking reports of monthly energy contributions from the various PV projects. The PV Pioneers program, for example, is monitored on a monthly basis at the same time the normal utility meter is read. A utility staff member, while at the resident's home, reads the PV meter which is mounted directly above the normal electric meter using a specially-designed bracket. Larger projects like PV1 and PV2 have been extensively metered on a daily basis for the past 10 years.

Most of SMUD's PV projects are monitored simply to make sure they are running properly. Program staff are pleased to report that they have had virtually no surprises related to the energy outputs of their PV projects. (A fire at PV1&2, however, posed a significant challenge to the program!) Engineering estimates, coupled with known climatic conditions make monitoring efforts relatively simplistic and routine.[R#20]

The 200 kW Hedge Substation is a PVUSA host sight that boasts SMUD's most sophisticated monitoring equipment. At the substation SMUD has employed a data acquisition system (DAS) and other grid-interface components which are housed in an air conditioned equipment building on the premises. The DAS simplifies the gathering of routine system performance measurements for this precedent-setting project whose impacts will be carefully studied by utilities across the country.[R#1]

Measuring the energy output of PV systems is more complicated given seasonal fluctuations, weather patterns, site-specific shading, as well as the type of mounting that the systems have. Naturally, PV systems that track the sun's rays over the course of the day produce more electricity than fixed systems. SMUD's PV program employs both fixed arrays and single-axis tracking systems. As such, SMUD has adopted a convention to calculate energy contributions from these systems differentiating between the nominal and effective kW output of different systems. SMUD uses an Energy Production Factor (EPF) of 1.23 for single-axis tracking systems and 1.00 for fixed systems, a factor that acknowledges the greater energy savings from tracking systems. Established by UPVG, the EPF provides for a more appropriate comparison between fixed and tracking systems.

Program manager, Don Osborn, notes that all PV systems are rated based on the AC output of the system at PVUSA test conditions. This standard is used by the utility industry and is typically 10% more conservative than the Standard Test Conditions (STC) ratings used by the PV industry.

EVALUATION

No formal evaluations by outside consultants have been performed on SMUD's Solar PV program to date. This is because the projects have not needed any evaluation since they have run smoothly, trouble-free, and have produced significant energy contributions at the lowest price for solar energy on the market without involving costly evaluations.

The PV Pioneers program, slightly more complex to implement because of its involvement with various residents in the community, has had a scientific market research telephone survey to establish the potential customer participation base for this project. The market research was performed by META Information Services in early March of 1993. The survey determined the potential participation levels for three different categories: the general public, SMUD EV Pioneers (customers showing a strong interest and support of electric vehicles), and "green" consumers (members of Sacramento area environmental groups).[R#18]

The market research showed that 26% of the general population, 32% of the EV Pioneers, and 57% of the "green" population would be willing to pay a premium price (15%) for PV generated electricity from their rooftops; and 70% of the general population, 74% of the EV Pioneers, and 88% of the "green" population would be willing to participate in a general "green pricing" program of 1 to 10% of the utility bill to establish a "Clean Energy" program that adds renewables, such as PVs, to the District's system but to necessarily on their own roof.[R#1,18]

Program Energy Contributions

CAPACITY CONTRIBUTIONS BY PROJECT (kW)	1984-1992	1993	1994	TOTAL
PV1	1,000	NA	NA	1,000
PV2	1,000	NA	NA	1,000
PV Pioneers	NA	432	472	904
Hedge Substation	NA	200	317	517
Coml PV Buildings	NA	100	144	244
Total	2,000	732	933	3,665

DATA ALERT: To calculate the energy contribution of the Solar PV program The Results Center uses an average annual load factor of 20% for fixed-axis systems and 25% for single-axis systems in this Profile.

SMUD's energy contributions from solar PVs began in 1984 with the 1 MW PV1 solar photovoltaic generating station. In 1986, the 1 MW PV2 station came on-line. Today, SMUD has a number of PV programs that result in energy contributions to the grid.

In 1994, total energy contributions from SMUD's solar PV installations are calculated at 1,792 MWh. Since 1984, total annual energy contributions are 7,524 MWh and cumulative energy contributions total 63,971 MWh.[R#1]

The capacity contribution in 1993 was 732 kW. Capacity contributions increased 28% in 1994 to 933 kW. Since 1984 SMUD's solar PV program has resulted in a total of 3.665 MW of capacity contribution.[R#1,4]

By project, SMUD's PV1 and PV2 solar power stations have produced the greatest capacity contributions at 1 MW each. The 1994 PV Pioneer systems were supplied by two contractor teams for a total of 134 systems and 472 kW. With 432 kW of capacity contributions in 1993, the PV Pioneers program has produced a total contribution of 904 kW in just two years of operation. The Hedge substation project has produced a contribution of 517 kW in two years and the Commercial PV Buildings program contributed another 244 kW in its two years of operation.[R#4]

PARTICIPATION RATES

The PV Pioneers program is the only one of SMUD's PV programs that is comprised of participants. In 1993, over 600 residents of Sacramento volunteered to participate in the PV Pioneers program. Of these, 108 were chosen to have the installations performed. In 1994, once again hundreds of residents volunteered for the program and 134 installations were actually performed. In two years of operation, the PV Pioneer program has resulted in the installation of 242 solar rooftop PV systems.[R#4]

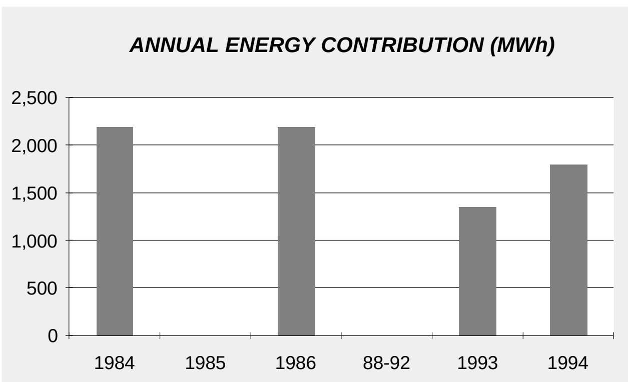
PV PIONEERS PARTICIPATION	NUMBER OF VOLUNTEERS	NUMBER INSTALLED
1993	600	108
1994	NA	134
Total	600	242

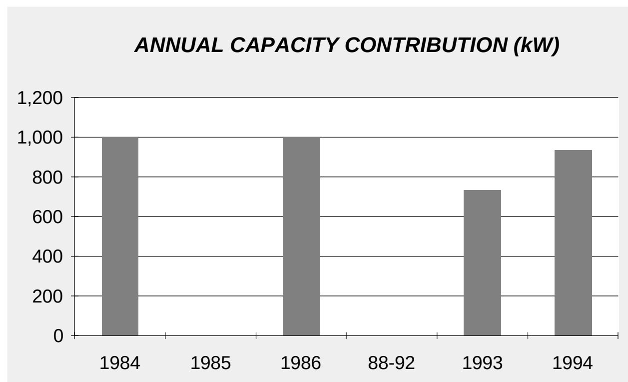
SMUD expects this program to continue to grow. In 1995, SMUD plans to install 100 rooftop PV systems, contributing an additional 400 kW of capacity to the grid as well as additional substation, parking lot, and building-integrated systems.

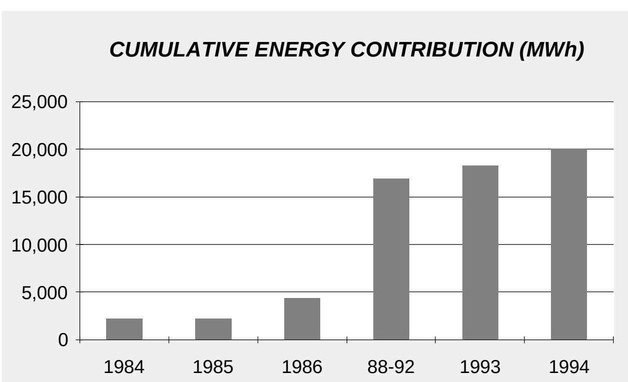
MEASURE LIFETIME

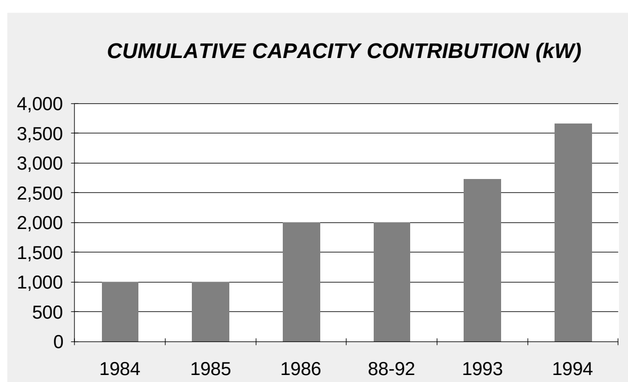
Since solar PV equipment has no moving parts and is virtually maintenance free, the average measure life SMUD assigns to it is 30 years with periodic O&M and invertor maintenance and replacement. Due to the newness of PV technology, the average measure life for PV installations has not been thoroughly tested in the field. PV arrays could last 30 or maybe even 50 years, while invertors last 15 to 20 years. In calculating

ENERGY CONTRIBUTION	ANNUAL CAPACITY CONTRIBUTION (kW)	CUMULATIVE CAPACITY CONTRIBUTION (kW)	ANNUAL ENERGY CONTRIBUTION (MWh)	CUMULATIVE ENERGY CONTRIBUTION (MWh)
1984	1,000	1,000	2,190	2,190
1985	0	1,000	0	2,190
1986	1,000	2,000	2,190	4,380
1988-1992	0	2,000	0	16,905
1993	732	2,732	1,352	18,257
1994	933	3,665	1,792	20,049
Total	3,665		7,524	63,971









the cost of saved energy, The Results Center has used the average measure life of 30 years recommended by SMUD.

PROJECTED SAVINGS

In 1995 SMUD plans to install between 800 and 900 kW of capacity from various PV programs. This includes a 214 kW nominal output tracking substation PV system, a 100 kW building integrated rooftop system, a 150 kW parking lot PV system whereby solar panels are used as roofing for cars, and 100 residential PV Pioneer systems. They plan to install all of this at roughly $6.00/watt.[R#20]

Cost of the Program

SMUD has been ramping up its Solar PV program since 1993 when the utility spent a total of roughly $4.5 million. In 1994 SMUD spent approximately $5.9 million, a 30% increase over 1993. In 1995 SMUD plans to spend about the same as in 1994. Total spending on the PV program for the three years combined is estimated at $16.3 million. Of this total, labor accounts for 7% while the installation of equipment accounts for 93% of all costs involved in the program. These costs include PVUSA membership, a Sacramento test facility, a PV DSM demonstration study, all PV installations, a mobile charging station, and SMUD labor. Over 95% of costs for each year have gone towards PV installations.[R#4]

Based on a dollar cost per watt, SMUD's initiatives have assisted in the facilitation of a nationwide cost reduction in solar PV installations. In 1993 for example, SMUD distributed a request for proposals to install its PV systems. The Hedge substation's turn-key system price was $6.26 per watt. When the utility "add-on" was included the cost for the Hedge station increased by $3.89 per watt totaling $10.15 per watt. This add-on includes interconnections, metering, site preparation, labor, administration, overheads, taxes, and bonding. In 1994, after one year of implementation, the process became much more streamlined. With a turn-key cost of $6.10 per watt and an add-on cost of $0.87 per watt, the total cost to install the solar substation was only $6.97 per watt, a $3.18 per watt or 32% reduction in only one year. In 1995, the cost per watt to install solar PVs for the substation reduced even further to a total of $6.62 per watt, a 5% decrease from 1994.[R#1,4]

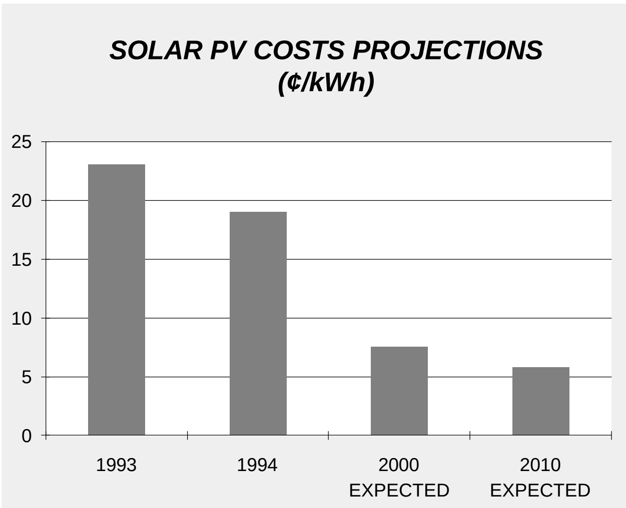
Similarly, the PV Pioneers program resulted in cost reductions for solar PV installations. From 1993 to 1994 the cost to install the PV Pioneers program went from $8.78 to $7.13 per watt, a $1.65 per watt or 19% reduction.

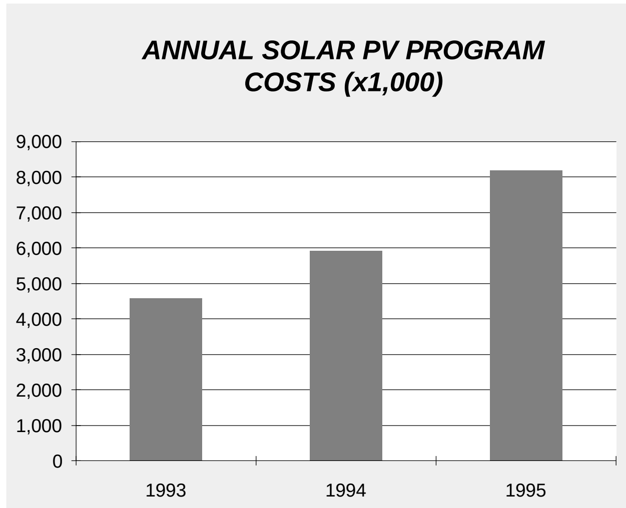
COST EFFECTIVENESS

SMUD has calculated a preliminary estimate of the cost of solar PV produced energy to be 18-20 ¢/kWh for the current PV projects. The most recently installed projects are being installed at 18 ¢/kWh. These costs, set for a 30-year measure life, include operations and maintenance, although they do not include a 1.5 ¢/kWh production payment or the DOE cost share.[R#4]

1993-1995 PV COST IMPROVEMENT	*TURN-KEY COST ($/W)*	*SMUD ADDED COST ($/W)*	*TOTAL COST ($/W)*	*30-YR ¢/kWh*
Hedge Substation 1993	6.26	3.89	10.15	32
Hedge Substation 1994	6.10	0.87	6.97	21
Hedge Substation 1995	5.71	0.91	6.62	18
2-Year Improvement	0.55	2.98	3.53	14
Residential Rooftop 1993	7.70	1.08	8.78	23
Residential Rooftop 1994	6.23	0.90	7.13	20
Residential Rooftop 1995	5.98	0.89	6.87	18
2-Year Improvement	1.72	0.19	1.91	5

SMUD COSTS OVERVIEW	1993	1994	1995	TOTAL
Total	$4.5	$5.9	$5.9	$16.3





PV COST PROJECTIONS ($/watt)	1993	1994	2000 EXPECTED	2010 EXPECTED
Modules	4.63	4.00	1.50	1.00
Panelizing	0.56	0.28	0.15	0.10
PCU/Invertor	1.20	1.00	0.15	0.10
BOS/Install	1.13	1.00	0.70	0.70
Other	0.18	0.20	0.10	0.10
Total	7.70	6.48	2.60	2.00
Utility Add-on	1.08	0.90	0.28	0.21
Grand Total	8.78	7.38	2.88	2.21
30 Yr ¢/kWh	23.0	19.0	7.5	5.8

COST COMPONENTS AND PROJECTIONS

Historically, the limiting factor on installations of solar PVs has been costs. In 1993, the cost of modules alone was $4.63 per watt. Other costs include: panels at $0.56 per watt; invertors at $1.20 per watt; installations at $1.13 per watt; and miscellaneous costs at $0.18 per watt. With a utility add-on of $1.08 per watt, the total cost for one watt of solar PV was $8.78. According to SMUD calculations, this is equal to 23 ¢/kWh for a 30 year measure life.[R#1]

In 1994, the average cost for solar PV was $7.38 per watt or 19.0 ¢/kWh, a 16% reduction in one year. By the year 2000 SMUD projects the cost to drop to $2.88 per watt and 7.5 ¢/kWh, a 61% reduction over 1994. By 2010 SMUD projects the cost of solar PVs to decrease even further to $2.21 per watt and 5.8 ¢/kWh, a 70% reduction over 1994 costs and on par with other sources of electricity.[R#1]

LESSONS LEARNED

Program managers at SMUD feel that the Solar PV program is running smoothly. SMUD aims to increase the PV projects that it currently is pursuing. SMUD has learned numerous lessons that will result in facilitating the increased applications of solar PVs not only in its territory, but also nationwide.

The solar industry needs a reliable and long-term market volume to develop and achieve long-term cost reductions required for full commercialization of photovoltaics: According to Don Osborn, SMUD's Solar Program Director, current "cost-effective" 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 prices, 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.[R#6,18]

It is important to analyze total expenditures and total capacity savings over the life cycle of solar equipment for 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.[R#6,18]

Sustained orderly development and accelerated commercialization will not occur early by simply relying on natural market forces: Accelerated commercialization won't occur just by implementing demonstration projects and watching cost curves. Utilities and other bulk purchasers must commit to an early and sustained series of purchases to permit the industry to invest in expanded production and automation. The current thinking among progressive utilities is the "diffusion model" of PV commercialization, where high value applications are identified and filled, then the next value level is developed. This has not resulted in a sufficient aggregation of order commitments to allow the needed expansion of production. Instead of this fairly passive approach, SMUD staff believe that utilities need to take a proactive role in commercialization of grid-connected PV applications. Utilities need to make multi-year commitments for substantial and continuing, multi-megawatt per year purchases.[R#6,18]

Support by the other stakeholders in the process, especially by the regulators, and an explicit DOE cost sharing will be required to close the early cost-value gap and make the process work: SMUD staff believe that the utility community must take the responsibility to get this process underway now and work with regulators, customers, and other stakeholders to make it successful. The national UPVG is proceeding with a utility PV purchase program that includes DOE shared-risk to jump-start the process. The program, 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 provides about 30% of the estimated $513 million program.[R#6,18]

Barriers to mass production of PV cells must be overcome: The widespread application of solar cell technology is driven by three factors: substantial reductions in production costs, increases in conversion efficiency, and optimizing energy yield through better tracking. PV modules represent about half of the cost of a PV system. The production cost of single crystalline silicon PV cells is very high and not amenable to automated production. Several alternatives in materials used as well as conceptual design changes show great promise for cost reductions.

There are two primary barriers to implementing solar PV in the residential sector; the most formidable barrier is cost: Solar PV prices are market driven. Historically, the costs to implement residential solar PV have been high, however the costs have decreased over the past few decades, ranging from $15 per watt in 1980 to $6.24 per watt in 1993. This has caused applications to be limited to remote homes and utility-backed residential programs.[R#20]

Another barrier to residential PV implementation is finding suitable sites. To combat this barrier, SMUD staff have approached from two sides, the customer and the architect. This means locating residential rooftops with south or southwest facing orientations. Presently this is not too large a problem simply because SMUD is only implementing PVs on a small scale. However, as more and more homes are retrofitted with rooftop PVs, availability of properly oriented roofs will diminish. This problem is only further exacerbated by architects who refuse to design homes with southern exposed rooftops. SMUD PV program managers note that it costs nothing to simply design a home's roof with the proper southern orientation. Architects maintain that the artistic integrity of their designs cannot be compromised by roof orientations.[R#20]

In the future SMUD program managers would like to see zoning laws implemented that treat south facing roofs as energy assets, not simply shelters. SMUD staff believe that a mandate could bring solar PVs to the consciousness of the homeowner. If home buyers request solar PVs before ever purchasing a home, market forces will require architects to respond by developing these types of homes.[R#20]

The SMUD Solar PV program managers project that eventually solar PVs installed on people's roofs will become commonplace and that someday roofing materials will be made from PV materials. However, due to oddly shaped roofs or roofs shaded by trees, roughly 25% of all homes are currently amenable to rooftop PVs.[R#20]

TRANSFERABILITY

Fundamentally, the transferability of SMUD's Solar PV program is a matter of political will. Just as the citizens of Sacramento have made clear their support for the long-term development and commercialization of solar technologies, other jurisdictions must assess the viability of such a program, a program that cannot be considered cost effective today, but which certainly will be a key component of utilities' resources in the future. This political will must be present in regulatory commissions for investor-owned utilities and in local governments for municipal and other publicly owned utilities.

This is not to say that PV programs can only be run where political support already exists. Just the opposite appears to be true: Champions and other advocates can provide the leadership to usher in an awareness of PVs and can speak eloquently on behalf of the opportunities (and perhaps imperative) that utilities have to promote and commercialize PVs so that they become cost effective resources as soon as possible. Thus the political will can either be inherent in a community or can be cultivated by citizens or utility staff.

SMUD recognizes that it can best serve the needs of its customers and the community at large by providing reliable access to cost-effective non-polluting solar applications as part of its responsibilities as an energy service company. Over the next several years SMUD plans to bring down the costs of photovoltaics, hopefully in collaboration with the federal government and other stakeholders in renewable energy development. Working with SMUD, other utilities and government agencies can create a synergy, a synergy that will translate into lower costs and expanded applications.

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