Arnold Schwarzenegger
Governor

PHOTOVOLTAIC MARKETS AND TECHNOLOGIES

PIER FINAL PROJECT REPORT

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Prepared By:
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Prepared By:
Solar Electric Power Association
Technical Assistance from: Technology Transition Corporation
Steve Hester, Tara Willey, Jeff Serfass
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Gerald Braun
Contract Number: BOA-99-190-S

Prepared For:
Public Interest Energy Research (PIER)
California Energy Commission

Hassan Mohammed
Contract Manager

Kenneth Koyama
Office Manager
Energy Generation Research

Martha Krebs, Ph.D.
PIER Director

Thom Kelly, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

Melissa Jones
Executive Director

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Environmentally Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration
- Transportation

Photovoltaic Markets and Technologies is the final report for the Sacramento Municipal Utility District ReGen Program (Contract Number 500-00-034), conducted by Solar Electric Power Association. The information from this report contributes to PIER's Renewable Energy Technologies program.

For more information on the PIER Program, please visit the Commission's website at: http://www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

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Abstract

The Sacramento Municipal Utility District teamed with the Solar Electric Power Association and the photovoltaic (PV) industry to investigate and report on PV incentive programs and the status of the PV industry. This project studied PV programs at Sacramento Municipal Utility District along with the experiences of Solar Energy Power Association, including the U.S. Department of Energy-sponsored TEAM-UP solar deployment program. The project team interviewed industry experts on the status of the PV industry. This report describes results from Solar Energy Power Association's study of the California market for PV, details Sacramento Municipal Utility District's efforts in PV, and explains options for the development and implementation of future utility-sponsored PV programs. Several critical factors that lead to a successful PV program are described, including adequate technology development, alignment of state and federal policies (interconnection, metering, and incentives), utility acceptance, distribution and service infrastructure, an informed market, and available financing options. An "Action Template for a Utility PV Program" outlines the steps needed to develop a utility PV program and the resulting components of the program. This report includes discussions on the initial stages of a PV program, developing the local infrastructure, partnerships, marketing, and deployment strategies. Conclusions are drawn with regard to policies of utilities and government in areas such as renewable portfolio standards, interconnection, and net metering. New and retrofit residential, commercial, and utility-scale markets, as well as off-grid applications for PV, are considered.

Keywords: Solar Electric Power Association, Sacramento Municipal Utility District, photovoltaic, PV, TEAM-UP solar program, U.S. Department of Energy

Executive Summary

Introduction

The Solar Electric Power Association studied photovoltaic (PV) markets, technologies, and deployment strategies for the Sacramento Municipal Utility District (SMUD) under SMUD's ReGen Program. SMUD has been the PV leader among utilities for several years and is considering how best to take PV "to the next level" in its service territory. This report details SMUD's efforts in PV, describes the results of Solar Energy Power Association's study of the California PV market, and explains options for utility-sponsored PV programs.

Purpose

The Solar Energy Power Association analyzed PV markets and recommended actions for the next phase of PV commercialization for energy service providers in California, including SMUD and other market stakeholders.

Project Objectives

This project developed and provided information for utility PV deployment efforts. The specific objectives included:

- Obtaining the best technical and market information for planning, developing, and implementing PV programs at California's electric utilities.
- Identifying options for expanding the solar energy market in the Sacramento region and throughout California.

The target audience is the electric utilities and utility stakeholders since they are central in developing PV markets. Studies show that PV can provide value to a utility and support from a local utility is critical for customers using PV.

Project Outcomes

The principal barriers to increased market acceptance are the high cost of PV and the lack of infrastructure for marketing, sales, installation, and maintenance. This study identifies a number of PV benefits, including:

- Simplicity, abundance, and scalability.
- Free energy source.
- Minimal environmental impacts.
- Support for the local distribution system.
- Ability to be installed on almost any building.
- Local control of generation.

- Local job creation.

The authors verified critical success factors for utility PV deployment programs and developed a new template that SMUD and other utilities can use to plan and implement a PV program. This study concludes that PV can satisfy several utility business goals, such as:

- Reducing costs to customers.
- Increasing system reliability.
- Enhancing utility revenues.
- Improving the utility's image.
- Maintaining and increasing the base of satisfied customers.

Conclusions

Incentives Necessary

Because of the high installed cost of PV systems, incentives are still necessary tools for PV market development. Incentives can create owner payback periods of 7 to 10 years for residential PV systems and 4 to 6 years for commercial-sector PV systems. Buy-downs or energy production incentives from the state, community, or electric utility will continue to be critical, but they must be long-term and multi-year, even if the amounts decline during the duration of the incentive program.

Factors Critical to the Success of a PV Program

Solar Energy Power Association had previously identified several critical factors that lead to a successful PV program. This study verified these factors, described in detail in Section 3, that include adequate technology development, alignment of state and federal policies (interconnection, metering, and incentives), utility acceptance, distribution and service infrastructure, an informed market, and available financing options.

Action Template for a Utility PV Program

This study introduces a new tool designed to assist utilities as they plan PV business activities. The "Action Template for a Utility PV Program," found in Section 3, outlines the steps needed to develop a utility PV program and the resulting components of the program. It includes discussions on the initial stages of a PV program, developing the local infrastructure, partnerships, marketing, and deployment strategies.

The Utility Role in Photovoltaics

Utilities are key stakeholders to commercialize PV, since PV is likely to displace traditional sources of revenue for utilities in the long term. Potentially useful utility roles include directly implementing utility-owned systems as well as facilitating customer-owned PV systems that benefit utility operations through public education and outreach, market research, and partnership building. Utilities can benefit from these activities because renewable energy

generation, including PV, is increasingly recognized for its ability to provide energy cost stabilization, a hedge against fuel price escalation, emissions reduction, and customer satisfaction. Utilities will benefit by including these considerations in their system planning and decision-making processes.

Recommendations

Recommendations for PV are provided in Section 4 and divided into the three major audiences: Utilities, government, and the PV industry.

Recommendations for Utilities

Utilities are encouraged to consider the Utility Action Template and are recommended to conduct analyses of summer peak demand periods, time-of-use rates, and time-of-use net metering to determine how PV could be used to best address a utility's peak period difficulties. Utilities should encourage builders to include PV in new construction projects because, compared to retrofit projects, PV in new construction is more cost effective and likely to perform better. The results indicate the value of case studies and workshops/seminars to engage a broad audience of builders. Utility assistance and incentives offered to customers and builders could greatly enhance market development.

Recommendations for Government Action

The results provide areas that government agencies can use to promote the use of PV, including adopting building code changes; establishing solar research, development, and deployment (RD&D) programs with incentives; investigating interconnection standards, net metering, and tax incentives; and renewable portfolio standards. A clearinghouse for accurate performance, cost, and value information on Zero-Energy Homes is needed.

PV Industry Recommendations

The PV industry should use accepted standards for calculating the performance of its products and communicate performance in consistent terms. Marketing efforts must be expanded. A broader array of building-integrated PV roofing products is needed. As the industry markets PV to end users, it should educate utilities about the values and business opportunities of PV. The PV industry should encourage local policy makers to quantify the value of emissions offsets, improving the economics of PV. Contractor training and certification is needed as manufacturers and distributors will ultimately have to assume the prime responsibility for training contractors to use their products. The study found that, ultimately, the PV industry requires a sales and installation infrastructure that will make the purchase of a PV system as easy as the purchase of a furnace or heat pump.

Benefits to California

This project and results provide significant value to California by developing and sharing information that, when used with the Utility Action Template, helps utilities and energy service providers in California start and expand PV programs in a more cost-effective manner. The report highlights how valuable and necessary incentives for PV systems are at this time.

California can benefit from expanding the PV market as the state has the largest and most significant PV market in the United States, some of the best sunlight in the nation, and a statewide peak load shape that matches with PV system energy output.

The study identifies the value of PV to California, by creating jobs, improving air quality, reducing dependency on scarce water supplies, minimizing noise, avoiding transmission constraints, and reducing dependency on imported electricity to the state. PV benefits utility transmission and distribution system with its locally sited distributed generation.

1.0 Introduction

The Solar Electric Power Association (SEPA) worked on this project from late 2002 to early 2004, with staff support from Technology Transition Corporation (TTC) under the guidance of the SEPA R&D and Commercialization Task Force (Task Force). SEPA created the Task Force to assist in the development of this project, and is composed of five members of the SEPA Board of Directors. The members of the Task Force and pertinent TTC staff are listed in Appendix A. Information from SEPA programs, reports, and position statements were utilized for this project. The project team interviewed more than 40 photovoltaic (PV) manufacturers, PV contractors, SMUD personnel, California utilities, and other stakeholders. SEPA also conducted an extensive literature search.

This report presents several strategies for utility PV deployment, taking into account factors that influence the market and what can be reasonably accomplished within the utility regulatory structure. The strategies focus on California's electric utilities, including municipal utilities, investor-owned utilities (IOUs), and rural electric cooperatives (RECs). This report concludes with recommendations directed to PV stakeholder groups to help expand the PV market and achieve broader commercial acceptance.

TTC staff knowledge encompasses more than 20 years of PV experience. For this project, SEPA's Board of Directors and members contributed industry perspective to the work, and the SEPA programs, reports, and position statements utilized include:

- Multiple reports from the Technology Experience to Accelerate Markets for Utility Photovoltaics (TEAM-UP) program, a 7.2-MW_{ptc}, $75 million PV deployment program with federal cost-sharing.
- Interconnection Guidelines for Utilities.
- Solar Power Solutions Report: The Business Case for PV.
- PV Value Statements for Industry Segments.
- Technical Specifications for PV Systems, which were used in TEAM-UP and the Solar Power Solutions (SPS) programs.
- Zero Energy Homes – Utility Benefits Report.

This is the final report in the series of report deliverables for this project, which included:

- SMUD's PV Program and Sacramento Markets.
- Commercialization Experience.
- Economic Assessment of PV Deployment Strategies.
- Management Assessment and Duplication of Effort.
- Assessment of the SMUD PV Program and California Markets: Conclusions and Recommendations.

- Photovoltaic Markets and Technologies: Assessment and Recommendations.

1.1 PV Programs at SMUD

SMUD has pioneered the development of PV programs in the early 1980s when it built a 1 megawatt (MW_{stc}) PV system at its Rancho Seco nuclear facility. SMUD has installed utility-owned PV systems on its customers' roofs, sold PV at discounted prices to its customers, partnered with stakeholders to build a PV manufacturing plant in its territory, participated in numerous cost-shared state and federal projects, and has been an entrepreneurial force for PV in the utility industry. SMUD has shared its knowledge of PV with other utilities internationally.

Utility interests have greatly influenced the PV industry's recent evolution and growth. Between 2002 and 2004, the SMUD PV program has experienced considerable upheaval and change. Recommendations identified by this report are designed to: (1) help SMUD direct its future PV programs; (2) help expand the markets for PV in Sacramento, the state of California, and the United States; and (3) help other utilities learn from SMUD's extensive PV experience.

1.2 The Cost of PV Systems

PV system costs have been declining for three decades and will continue to decline even though short-term supply limitations may cause prices to temporarily increase. The PVUSA Project and recent SMUD experience provide some cost figures for comparison. In the PVUSA period of 1996 through 2000, the total installed costs of large commercial-sized PV systems (greater than 70 kW_{ptc}) ranged from \$6,000/kW_{ptc} up to \$11,000/kW_{ptc}.

Total installed residential-sized PV system (1 to 5 kW_{ptc}) costs ranged from \$8,000 to \$11,000/kW_{ptc} for the same period. In the SMUD program during 2002, the total installed residential PV systems costs averaged \$6,540/kW_{ptc}, with \$3,710/kW_{ptc} for PV modules, \$1,190/kW_{ptc} for inverters, and \$1,640/kW_{ptc} for installation, not including SMUD transaction and management costs.

During 2002 there were 678 installations of 1 to 5 kW_{ptc} systems, mostly in the 1.8- to 2.9-kW_{ptc} range. The California Energy Commission estimated that by late 2005, 3 kW_{ptc} PV systems should be able to produce \$0.23/kWh energy without incentives in California. The Energy Commission projects that by 2017, PV will be cost competitive without rebates at \$0.126/kWh.

1.3 Solar Resources and Technologies

Sunlight strikes the earth each *minute* with more energy than the world's human population consumes in a year. At any given surface location it is not constant, varying by time of day, time of year, climate, and global position. The intermittent nature of sunlight creates challenges for an electric utility. On the other hand, peak production from a PV system can coincide fairly well with the summer peak period of many electric utilities because sunlight is often abundant when air conditioners are operating at maximum capacity.

The most widely used PV cell material is silicon, highly purified and sliced into wafers from crystal ingots, or grown as thin ribbons. The efficiency of silicon cells in converting the sunlight to electrical energy is typically 14 to 18%, with one-of-a-kind laboratory cells reaching more

than 25%. Other semiconductor materials are also used for PV modules. The promise of thin-film technology, with its less costly manufacturing processes and materials but lower efficiency, is yet to be fully realized. Ultimately, real technology breakthroughs in product costs, expanded manufacturing volumes, and the variety of flexible and rigid products that can be produced economically, should reduce costs and drastically expand the market for PV.

There are various mounting techniques for PV modules. PV systems are most commonly mounted on rooftops or on ground-anchored structures. Rooftop systems are typically mounted either above the roof or as part of the roof itself. The latter technique is referred to as a building-integrated PV (BIPV) system. Companies have designed mounting systems for commercial-sector flat roofs that do not penetrate the roof. For residential and small-commercial pitched roofs, manufacturers are developing shingle and tile-like BIPV modules. When PV systems are integrated into a building envelope, they contribute more than the energy produced — they contribute value as a building material.

The combination of PV and building energy efficiency is potent and is leading to the development of zero-energy buildings (ZEBs) and zero-peak buildings (ZPBs). These are buildings that draw significantly less energy from the grid on an annual basis. The goal is for developments to eventually yield buildings that are zero net energy users for the entire year. ZPBs are buildings that draw no electrical energy from the grid during a utility's peak-demand period. These buildings have both PV systems and enhanced energy efficiency measures and may include energy storage. Net metering is mandatory to make ZEBs and ZPBs financially feasible for the building owner.

1.4 PV Market Size and Growth

The most cost-effective applications for PV are typically off-grid, where PV provides wireless service more cheaply than extending the distribution system. This is particularly true in remote areas where line extension costs are high, but may even be true when the line extension is no more than across a street or highway. Nevertheless, the fastest growing market segments worldwide and in the United States are now grid-connected applications, encouraged by public policy directives and incentive programs designed to stimulate the growth of grid-connected PV markets.

The manufacturing and sales of PV system components, fueled by growing demand, have been expanding rapidly for a decade or more, with steady growth of 25 to 40% per year. Worldwide module annual production was about 600 MW_{stc} in 2002, 750 MW_{stc} in 2003, and approached 1 $gigawatt_{stc}$ in 2004. The United States market has also been experiencing strong growth since the mid-1990s. The United States is the third largest market in the world, behind Japan and Germany. The nation lags largely because of low competitive energy costs, but markets grew 15 to 20% in 2002, approaching 60 MW_{stc} annually.

California is the largest grid-connected United States market, with a total installed capacity approaching 60 $MW_{ptc\ in\ 2004}$. Municipal utilities in Sacramento and Los Angeles lead the way with their PV programs, and a number of other California cities also provide incentives. One of the stimulants for the PV market in California has been the state's energy crisis that occurred in

2000 and 2001. Rolling blackouts and brownouts triggered a number of consumer actions to secure a non-grid supply of electricity.

PV for niche applications, such as road-signs and remote water-pumping, has experienced strong market penetration and growth because PV is cost-competitive with other options. Grid-tied applications for PV are harder to sell because of the low cost of grid-supplied electricity. The availability of incentives, such as rebates and tax credits, has helped bring down the cost of PV, but the playing field is far from level. PV paired with energy efficiency measures often offers the greatest value to the end user, although this is often more difficult to implement with retrofit installations.

1.5 The Benefits of PV

The benefit "streams" that go beyond the value of the energy produced by PV are discussed throughout this report; SEPA recommends these be considered by utility management, government policy makers, and program participants, although their views of these factors will certainly vary. These benefits must be converted to economical cash flow streams, as done in this study, in order for a comprehensive evaluation.

1.5.1 Non-Energy Value of PV Systems

It is the non-energy value of PV that will cause utility and customer markets to continue to grow, even before economic cross-over points are reached. The cost of conventionally generated electricity fails to account for externalities, such as the adverse health impacts attributable to the mining/exploration, transportation, storage, cooling water needs, noise, and the emissions from the burning of fossil fuels. It also ignores the eventual impact of the depletion of these fossil resources. Research continues to quantify these externalities and provides a solid rationale for PV incentives. If the calculated value of the externalities exceeds the difference between PV and fossil-fuel power, then an objective analysis supports the deployment of PV. In practice, a comparison of fossil generation and PV rarely recognizes full externality valuation. In one case where it has been done, the National Park Service (NPS) has assigned defined values to emissions that can be used in purchasing decisions.[1] Other entities with an interest in clean air and stabilization of global environmental change may do likewise in the future.

1.6 The Utilities' Role in Photovoltaics

Utilities have a significant role in the commercialization of PV because they can facilitate or impede PV installations. Resolving issues such as interconnection and net metering is dependent on cooperation between utilities and the PV industry, including the owners of PV systems. Utilities can benefit by deploying PV and are increasingly viewing PV as a means to serve customers and help manage the grid. Renewables, including PV, are increasingly identified as:

- An option to help stabilize energy costs, providing a hedge against fuel price escalations.
- A pollution criteria response.

1. These values were to increase after September 1997 to \$0.85/lb. SO_2. \$3.75/lb. NOx, and \$14/ton CO_2.

- A response to customer demand.
- A response to customer desire for environmentally sustainable energy.

Based on work that SEPA has conducted, such as the TEAM-UP and Solar Power Solutions programs, several approaches to deploying PV have become apparent. Each has unique benefits and has been proven successful.

- Community Based — Public/private entities create partnerships between community groups, local businesses, local utilities, local government, and other stakeholders.
- Dealership Network — The project leader engages in multiple strategic alliances with distributors who market and sell PV products.
- Green Pricing — Customers pay a premium on their electric bills to support solar or other renewable energy supply options.
- Market To Customers — The manufacturer markets directly to customers and is responsible for public relations, marketing, and product development.
- Product/Technology Development — A new or improved product or technology is introduced to the market using a variety of techniques, including strategic partnerships, direct sales to homeowners, financing, and distributor networks.
- Schools — Ideal community sites for solar demonstration projects.
- Utility Partnerships — The technical knowledge of a PV business is combined with the resources, credibility, and technical knowledge of the utility to successfully deploy PV.

Significant barriers to widespread use of PV remain the high cost and the lack of a local marketing, sales, installation, and maintenance infrastructure. This infrastructure is required in order to ease consumers' concerns in the purchase of a PV system from a trusted business. These concerns are similar to those in the purchase of any other building or generation system. Other difficulties include inverter performance and a perceived lack of aesthetic appeal, both of which industry stakeholders are addressing. The PV industry is working hard to make PV a mainstream energy option and utilities are critical partners in this endeavor. Utilities have the capital, technical knowledge, and infrastructure to communicate and serve a broad customer base. The utility can, at a minimum, help ease net-metering and interconnection requirements for the PV end-user.

2.0 Project Approach

The goal of this project was to develop and provide information on and for utility PV deployment efforts. The specific objectives included:

- Obtaining the best technical and market information for the planning, development, and implementation of PV programs at California's electric utilities.
- Identifying the next options for solar energy market expansion in the Sacramento region and throughout California.

The project team analyzed SMUD's photovoltaic programs and the state of the photovoltaic business in general. The methodology, conclusions, and recommendations are intended to be useful for electric utilities throughout California and in other states, the PV industry, and Federal, State, and local governments.

The project included four tasks. Each task was formulated to produce a set of particular tools and deliverables. The tasks are described below.

Task 1 – Program Management Tool

The objective of this task was to develop a framework under which a large body of information could by analyzed and reduced to practical conclusions and recommendations. Various sources of information were utilized, including SMUD staff, TTC staff, SEPA's Board of Directors, SEPA members, staff at other California municipal utilities, PV manufacturers, and PV contractors.

SEPA established an R&D and Commercialization Task Force (Task Force) to provide technical and market guidance and to review and analyze the various products and reports developed under this project. The members of the Task Force are listed in Appendix A.

Task 2 – Assess PV Plans

The project team reviewed and analyzed SMUD's PV programs, and included past program activities and planned future actions in the analysis. Aspects of the PV business considered in the analysis include:

- PV applications
- Materials issues
- Installation techniques
- Mounting alternatives
- Building integration
- Aesthetic design
- Component performance
- Lessons learned

- Models for sustainable businesses

The project reviewed the history of SMUD PV programs, analyzed the planned and possible future program directions, and summarized industry experience as it relates to PV projects and California PV markets. These efforts provided a broad spectrum of program recommendations on product development, marketing, demonstration projects, project priorities, and program planning.

The key deliverables for this task were:

- Four reports documenting PV markets, PV deployment economics, lessons from commercialization programs, and a management assessment of SMUD's PV program.
- A final task report that presents the data from the first four reports and provides recommendations and conclusions for the SMUD program.

Task 3 – Market Expansion Options

An evaluation of market-expansion options for solar energy in Northern California yielded a set of programmatic recommendations, which are discussed in Section 7. While these were developed for SMUD, they are suitable for use by any electric utility seeking to market photovoltaic systems.

The work in this task built on the successes and lessons learned from the SMUD programs. The results were not based simply on the assumption that SMUD's programs would continue to be implemented as they were in past years. Rather, the recommendations are designed to help SMUD and other electric utilities adapt to a growing market for PV and a rapidly changing array of technologies and corporate players.

SEPA interviewed more than 40 stakeholders to gain information on marketing, commercialization, and implementation options for electric utilities. Stakeholder groups included current and past SMUD PV program staff, PV module manufacturers, system integrators, local and regional installation contractors, homebuilders, and commercial developers. The information collected during the interviews was documented in reports, analyzed, and used to shape the recommendations and conclusions of the entire project.

The key deliverables for this task were:

- A detailed analytical plan that outlines the processes needed to complete the work, and provides in-depth descriptions of the deliverables.
- Transcripts of work-plan and report review discussions by the task force.
- An interview guide that shaped the direction of the interviews toward relevant and unbiased information collection.
- Interview transcripts.

- A final task report that combines information from this task with information developed in Task 2 to make broad recommendations on PV development and PV programs at electric utilities.

Task 4 – Monthly and Annual Reporting and Invoicing

This task included the project's administrative activities such as monthly reporting, annual reporting, invoicing, and project reviews. The primary product of this task is the Final Report for the entire project.

2.1 Procedures

Several techniques were combined to collect data and develop recommendations. The authors used existing literature and prior SEPA knowledge to develop baseline information. SEPA then conducted a series of interviews to obtain the most current perspectives on:

- PV technologies
- PV markets
- SMUD and its PV programs
- Other utility PV activities

Literature Search

The literature search was extensive as it consisted of information from a variety of sources. Those sources included documents, reports, presentations, and websites from entities such as the California Energy Commission, California Public Utilities Commission, California Solar Center, California electric utilities, U.S. DOE, NREL, SEPA, TTC, and related documents from Utility Photovoltaic Experience (UPEx) conferences, TEAM-UP files and reports, and SEPA's Solar Power Solutions program project. Much of this information is referenced in the individual project reports.

Economic Analysis

SEPA conducted an economic analysis of strategies for PV deployment. This effort built on the results of another project in the SMUD ReGen Program, "Utility System Capacity and Customer Demand Value of PV." The primary deliverable in this project was a report by Dr. Tom Hoff of Clean Power Research titled "*Final Results Report with a Determination of Stacked Benefits of Both Utility-Owned and Customer-Owned PV Systems*." The methodology used by SEPA for the economic analysis was to establish a spreadsheet (based on Dr. Hoff's results) that determined the net present value and payback periods of various scenarios of SMUD's PV program, with results applicable to other utilities. The results are documented in Report 1.2.2.3, *Economic Assessment of PV Deployment Strategies.*

Interview List

The list of the interviewees was developed with the assistance of the Task Force, SMUD staff, and the Energy Commission. Those interviewed were granted anonymity in order to collect

candid information. The list included individuals and corporate employees. These interviews provided a unique perspective on developing PV markets and SMUD's activities within those markets. The interviewees included:

- Eighteen representatives from the electric utility industry.
- Nineteen PV industry representatives.
- Four other stakeholders.

Interview Guide

Dr. Scott Davis, Strategic Marketing Decisions, developed the interview guide with input from other sources. The interview guide was designed with unique questions to capture information from a diverse group of individuals in an unbiased manner, while allowing the respondent sufficient flexibility to offer suggestions and opinions. The interview guide was reviewed by the SEPA Task Force, and submitted to SMUD and the Energy Commission for approval. The interview guide consisted of a set of questions for each of the following five groups:

- Electric utilities
- PV manufacturers and installers
- Contractors and builders
- Cities and municipalities
- Residential and commercial customers

3.0 PROJECT OUTCOMES

3.1 Summary of Results

The primary results of this project are:

- PV is a rapidly growing, maturing, valuable energy technology that, with incentives, provides competitive electricity in selected situations.
- SMUD's PV program leadership provides experiences and lessons from which all utilities can benefit.
- Incentives at the federal, state, and local level can accelerate development of a sustainable PV market.
- Incentives, to be most effective, must be stable and consistent (even if they decline), be properly and adequately funded, and provide the continuity needed for typical PV system purchase and installation time frames.
- PV systems should be sold and purchased with a performance expectation; the system performance needs to be monitored to ensure expected operation and value.
- The SEPA effort has established an Action Template that addresses plans and strategies for utility PV deployment programs.
- This report documents recommendations that utilities, governments, the PV industry, and electric utility customers are encouraged to consider.
- The non-energy benefits of PV provide added value that will be increasingly important in purchase decisions.
- The results of this study have prime application in SMUD and other California markets, but can easily be applied to electric utilities throughout the nation.

3.1.1 PV Overview

The basic building block of PV technology is the PV cell, a device that converts sunlight directly into electricity. When sunlight is absorbed by a semiconductor layer in a PV cell, electrons are dislodged, creating an electric current. The higher the intensity of the light, the higher the current generated. PV cells are wired together to allow the current to flow in an external circuit and sealed to produce a PV module. The modules, usually the commercially sold PV component, range in power output from about 10 W_{stc} to 300 W_{stc}. A PV system often consists of one or more modules connected together in an *array*. This PV array is then usually connected to an inverter that changes its direct current (DC) electricity to alternating current (AC). This combination of modules and inverter is a PV system, and may include storage batteries if the system is designed to operate without grid support. A system with batteries can provide back-up power when the grid experiences a power outage. A utility-connected PV system that does not include batteries will not operate when the utility grid is down.

PV has been producing electricity for critical loads in remote locations, including the polar ice caps, the tropics, and satellites in space. There is a strong market in developing countries for stand-alone PV systems that provide electricity for homes, schools, hospitals, community buildings, water pumping, and other loads that cannot be served economically by the utility grid.

The largest growing market for PV today is utility customers that are already served by the utility grid. Individuals, companies, and communities choose PV because of a desire to implement a clean, sustainable energy source, the convenience of placing power generation at the source of demand, and the convenience of a generation source that requires no fuel, fuel storage, or delivery; emits no noise or emissions; and has no moving parts. Additionally, PV is a power technology that can be built right into building roofs, façades, canopies, and windows.

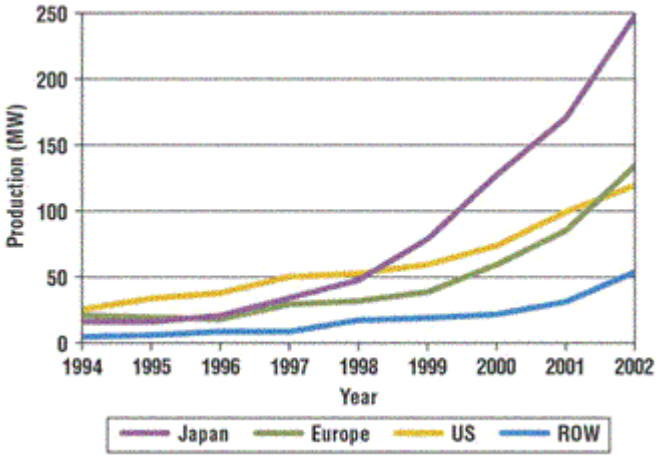

Figure 1. Growth in PV manufacturing worldwide

3.1.2 The PV Industry

The PV industry is evolving and growing at 25 to 40% per year, and the supply of PV components is increasing to meet market demand. The PV market has seen annual sales and production increases of more than 25% for several years with more than 40% in 2002, and with worldwide module production approaching 600 megawatts (MW_{stc}) (Maycock 2002). Worldwide module annual production was about 750 MW_{stc} in 2003 and approached 1 gigawatt (GW_{stc}) in 2004. The nation's market has also experienced strong growth since the mid-1990s.

The steep increase in the production curves shown in Figure 1 are the result of significant incentive programs in Japan, Germany, and, to a lesser extent, the United States, where most of the market increase occurred in California.

Many PV companies are experiencing significant growth. PV module manufacturers, the biggest of which are part of large oil, energy, and electronics firms, have reached a point where profits are being realized. As can be expected during this strong growth period, several PV companies have merged, some with global partners, and more mergers and acquisitions are expected. Increasing production capacity is expected to lead to cost reductions. Three large

module suppliers (Sharp, Sanyo, and Kyocera) have completed 100- or 200-MW_{stc} annual production facilities. BP Solar and Shell Solar have also increased capacity.

3.1.3 The Solar Resource

Each day more solar energy falls to the Earth than the total amount of energy the planet's 6.1 billion inhabitants would consume in 27 years.[2] Solar energy is variable, with hourly, seasonal, and geographic variances.[3] Except in the tropics, the sun is never directly overhead, and its intensity and angle vary by season. For example, solar radiation may vary from 92% (early summer) to 38% (early winter) of theoretical maximum insulation at latitude 45°. The average annual intensity at 45° latitude is 71% of maximum.[4]

Solar radiation values may be deceptive, especially from a utility standpoint. The value of the insulation for a particular location ignores the *capacity* value from PV. Recent work by the National Renewable Energy Laboratory (NREL) shows that high annual levels of insolation are *not* a necessary condition for finding useful sites for PV. A study involving about 35 utilities that correlated utility system daily load curves with PV production found that many utility areas with lower insulation levels had peak-day system load curves that correlated well with PV output curves. The same study found that a utility's summer/winter peak load ratio provided a good proxy of capacity contribution, with the higher ratios showing higher contributions (Perez 1993). Also, one of SEPA's early market evaluation efforts showed that PV can make a contribution to almost every utility in the country.

3.1.4 Photovoltaic Technologies

In 1839, Edmond Becquerel noticed that, in addition to heat, the sunlight that is absorbed by certain materials can produce small quantities of electricity. This curious phenomenon was limited to measuring light levels in photography until the 1950s. Then, in the early 1950s, the convergence of three factors led to the development of photovoltaic cells: (1) improved purification techniques for semiconductors; (2) advances in solid-state devices beginning with the development of the transistor in 1947; and (3) the electrical power needs of the emerging space program. In 1954, a 4% efficient silicon crystal photovoltaic cell was demonstrated. Today's typical silicon cells are 14% to 18% efficient. One-of-a-kind laboratory silicon cells above 25% have been made and cells using other materials in concentrated sunlight have exceeded 34% efficiency.[5]

The most widely used PV cell material today is crystalline silicon. It is highly purified and sliced into wafers from ingots or castings, or it is grown as thin sheets or ribbons. Polycrystalline silicon inherently makes less-efficient solar cells than single-crystal silicon, but it is also slightly less expensive to produce.

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2. U.S. Department of Energy, http://www.nrel.gov/documents/solar_energy.html
3. U.S. DOE, http://www.eere.energy.gov/state_energy/technologyoverview.cfm?techid=1
4. National Renewable Energy Laboratory, http://rredc.nrel.gov/tidbits.html
5. U.S. DOE, http://www.eere.energy.gov/solar/pv_quick_facts.html

Thin films offer a promising approach to producing solar cells. Commercial thin-film cells today are principally made from amorphous silicon. Copper indium diselenide and cadmium telluride also have promise as low-cost thin-film solar cells. The cost of materials for thin-film solar cells is considerably lower than that of crystalline or polycrystalline silicon. Thin-film solar cells can also be manufactured using a large-scale automated facility and in a variety of sizes and shapes, and can be incorporated into modules or building components.

Solar Modules and Arrays

The evolution of PV modules has paralleled the evolution of PV cells. PV modules are now a durable product that can have a lifetime exceeding 30 years. Modules consist of a transparent front material (usually low-iron glass), a number of PV cells, a cell encapsulant, and a back cover material. There is no standard module size, as each manufacturer's process and cell technology dictates an optimum size of module. A common size is approximately 18 inches by 48 inches. Several suppliers are exploring larger sizes to reduce costs associated with materials, shipping, installation, and wiring. A PV array (a grouping of PV modules) may be as small as a few modules, or may cover acres of land in a multi-megawatt utility power plant.

Balance-of-System

The term balance-of-system (BOS) is the name given to the equipment and activities of a PV system other than the PV modules. The BOS typically includes:

- The DC-to-AC inverter(s).
- The mounting structure for the modules.
- Electrical wiring and connection equipment.
- If utilized, storage components (usually batteries) and/or backup generation.

Recent efforts now include other important total PV system "soft" costs as part of the BOS. A more comprehensive listing[6] of BOS components could include:

- Project Management
- Engineering & Design
- Foundation (if ground-mounted)
- Component Procurement
- Sitting & Permitting
- Installation
- Electrical Protection & Safety Equipment
- Site Facilities
- Metering

6. Sandia National Laboratories, http://www.sandia.gov/pv/docs/BOS.htm

- Electrical Interconnection
- Data Monitoring
- Communications & Control (if needed)
- Operation & Maintenance

Tracking the sun increases the energy output of a PV system, but at increased cost and complexity. The purchase price, along with the installation and maintenance costs of a tracking system, must be compared to the energy output requirements of an application. Extensive testing at Arizona Public Service in Phoenix, Arizona, and at PVUSA in Davis, California, has shown that tracking in a north-south, one-axis configuration gives 21 to 27% more annual energy output when compared to a fixed array, at near latitude tilt, and two-axis tracking improves the annual output energy by 37 to 43% compared to a fixed array.[7]

Roof mounting techniques have proven to be a popular and cost-effective mounting strategy for PV modules on both flat and slanted roofs. A popular roof jack technique uses a plate for attachment to a flat roof or is directly bolted to a slanted style roof.

Balance-of-System – Inverters

One of the most important components of an AC PV system is the inverter that converts the PV array's DC electricity into conventional alternating current (AC). Two basic types of inverters are available: (1) grid-connected (also called line-commutated), which is used for synchronization with the utility's power system, or (2) a stand-alone inverter, for operation in a grid-independent mode with batteries. A special type of stand-alone inverter may be configured to operate while connected to the utility grid.

Grid-connected inverters must produce clean waveforms with minimal harmonics so they do not degrade the power quality of the utility grid. There are several nationally recognized standards that ensure the quality, safety, and reliability of grid-connected inverters. IEEE, UL, and other organizations have developed standards and testing processes to prevent unsafe operations of inverters.

An inverter must automatically disconnect from the grid if the utility grid is operating out of normal tolerances, including power outages. Several techniques have been developed that prevent the inverter from running without the utility grid, a condition called *islanding*.

Stand-alone inverters must provide a quality of power comparable to that of the utility grid and most new designs meet this requirement.

Inverters consume power when they are on and they are usually much less efficient when operating at low-load conditions (such as under cloudy conditions or early morning or late afternoon).

7. Sandia National Laboratories, http://www.sandia.gov/pv/docs/PVFEffEnergy_from_the_Sun.htm

The use of photovoltaics for stand-alone applications may require additional equipment, such as batteries (or some other storage medium), a charge controller (a solid-state device that prevents overcharging the batteries), or, if needed, a backup generation source. The PV modules used in stand-alone applications are usually the same as those used in grid-tied PV systems.

3.1.5 System Monitoring and Evaluation

The truth and accuracy of PV module ratings have been a problem for comparison and prediction purposes for years. The use of a DC module rating under standard test conditions (STC) in a controlled indoor environment is reasonable. Manufacturers predominately use an indoor flash chamber with controlled temperature, optical, and electrical conditions. The manufacturer can replicate standard conditions on production modules to determine if the manufacturing process is stable and is operating properly. The AC rating of an outdoor PV system, mounted on a roof or on the ground, is another matter.

PV systems are sold on a dollars-per-kilowatt basis. The highest rating gives the highest price for the supplier of the module, but this may create excessive costs for the buyer. The buyer will have an interest in the monthly or annual energy production of the PV system. A reasonably accurate system rating is required to predict the output of the PV system as it will be installed in the field. The PVUSA project in the late 1990s established the use of the PTC rating (PVUSA Test Conditions, which are defined to be 1000 watts per square meter irradiance, 1 meter per second wind speed, and at an ambient temperature of 20°C [68°F]). This rating has been a *de facto* outdoor, grid-connected, alternating-current rating methodology for more than a decade and provides a reasonable basis with which to compare different PV systems. It is recommended that the utility and PV industry continue to utilize the PTC rating criteria. It is also suggested that utilities and governmental agencies require PowerMark module certification, which utilizes a certification process that not only determines a rating for the PV module, but also requires successful selected IEEE, UL, and NEC certification testing to validate the durability and reliably of the modules.

Value analysis and payback calculations include the amount of energy and power produced. A method of predicting energy output and a corresponding rating for the power output of the PV system (both in kilowatt-hours and in kilowatts, respectively), is needed to justify the predominately up-front costs.

In addition to a system performance rating, a monitoring system is recommended for completed installations. Because a PV system contains no moving parts and does not make noise, the only method to determine proper operation is to monitor the electrical output of the inverter. The ability to measure energy output indicates that the PV system is operating as expected or it will show reduced output and identify the need for maintenance or repair.

If the PV system is connected to the grid under a net metering policy (net metering is described in detail in Section 3.1.9), the use of an additional kilowatt-hour (kWh) meter on the output of the inverter allows the owner to determine the amount of energy produced during any period.

It is recommended that buyers of a PV system require the seller to provide a prediction of the kWh output from the PV system for each month of typical weather conditions at the location of

installation. Any reputable manufacturer or installer will be able to give a good prediction of the output expected during each typical month of operation.

3.1.6 Building-Integrated PV (BIPV)

A compelling mounting strategy for PV systems is called building-integrated PV (BIPV). BIPV can include a wide variety of mounting and installation techniques. As the name suggests, the PV system is integrated into the building's structure. State-of-the-art PV modules are now available in a variety of colors and styles, allowing designers to use them as aesthetic elements built into roofs, skylights, awnings, entryways, and façades. Some PV modules can even be specified to transmit a percentage, usually 10 to 20%, of natural light. When PV systems are properly integrated into a building envelope, they don't just provide energy, but they also contribute to the structure itself (as shown in Figures 2 and 3). Since most buildings have windows or an exterior cladding it makes financial sense to have the windows or cladding produce energy, and the savings on conventional structural materials helps to offset the cost of the PV materials.

Figure 2. Early AstroPower building-integrated roof tile system installation
Photo Credit: AstroPower.

While it is clear that BIPV is the trend of the future, the technologies are available now, and several manufacturers are showcasing these technologies on their own buildings. A major skyscraper in New York City's Times Square includes PV panels on the façades of the building to replace curtain glass. PV atrium systems with semi-transparent glazing are not only functional, but also perhaps the highest-value application for BIPV. BIPV systems like these can show payback periods of fewer than 10 years in many regions. PV power is now built into roofing shingles and tiles that are both functional and easy to install; PV awnings and carports capture the sun's energy while providing shade from the sun's heat; and PV greenhouse windows power the business while sheltering plants.

3.1.7 PV in Combination with Energy Efficiency Technologies

Many businesses are looking for ways to reduce operating costs. A package that combines energy efficiency measures in a building with a PV system on the roof will reduce both energy usage and peak-period electrical loads. The combination of energy efficiency and PV can yield an optimized benefit/cost ratio to both the business and the utility.

Energy design strategies that are gaining increased interest are zero energy buildings (ZEBs), zero energy homes (ZEHs), and zero peak communities (ZPCs). A ZEH utilizes an excellent building shell, high-efficiency lighting, high-efficiency HVAC and appliances, and on-site PV generation (as shown in Figure 4). The goal is to minimize annual energy consumption from the utility grid. Because reducing net energy demand to zero may be expensive in today's markets (due to the high cost of extremely efficient building components, appliances, and HVAC equipment), the U.S. DOE Buildings program (www.buildings.gov) has set the first step for ZEHs as a home that reduces utility bills by at least 50%. In the future, the goal is to build millions of ZEHs that will actually reduce annual usage from the grid to zero.

Figure 3. Wilton Bible Church, Wilton, California, features a SunSlate BIPV roof.

Photo Credit: AstroPower

ZPCs are a concept that may prove to be more attractive to electric utilities. The goal in a ZPC is the construction of homes and commercial buildings that draw no power from the grid during the utility's summer on-peak period. This could be achieved primarily through the use of PV, a highly efficient cooling system, and a high quality building shell. To minimize the size of the PV system and maximize the benefit-to-cost ratio, it is likely that highly efficient lighting and appliances will also be necessary.

For ZEHs, an effort is now underway to familiarize builders and developers with the concept of energy efficiency and solar technologies. Needs that have been identified are:

- Communicating and quantifying the benefits of ZEHs.
- Developing information for builders and homeowners.
- Establishing collaboration between builders, utilities, and the PV industry.
- Achieving the technology and advancements necessary to make ZEH cost effective.

The PV industry has not effectively marketed PV and has not adequately educated consumers about PV technology, its benefits, costs, and expected maintenance. ZEHs face a similar problem but the problem is more extreme because ZEHs are, for the most part, a very new concept. In addition, the solution may be more complex because of the diversity of stakeholders involved, including:

- Production builders and the building trades.
- Electric and gas utilities.
- PV manufacturers and contractors.
- Solar water heating manufacturers.
- HVAC, appliance, and lighting manufacturers.
- Homebuyers.

For ZEHs, there is no clear champion for educating the multiple stakeholders. Builders in particular must be convinced of the benefits of ZEHs, and this requires accurate cost, performance, and market data. SEPA recommends establishing a clearinghouse for ZEH information, data, and marketing solutions.

Collaboration among utilities, builders, the solar industry, design professionals, and the construction trades will be required to achieve widespread adoption of ZEHs. Each party brings something important and necessary to the equation, and each stands to benefit. Utilities can benefit from reduced peak demand and improved performance of the distribution grid. Builders will benefit by having a unique product that will provide homebuyers with significant savings over the home's lifetime. The solar industry will benefit from steady growth as ZEHs become more popular, and those in the PV industry that specialize in residential systems will benefit the most.

Energy and rate analyses are needed to develop utility rate structures that will improve the financial feasibility of ZEHs and ZEBs.

One future option that could maximize the benefits of PV for utilities is information technologies that allow the utility to communicate directly with the home for the remote dispatch of loads.

Figure 4. Builders and solar installers both benefit from advances in solar technologies.
Photo Credit: AstroPower

For ZEHs, SEPA's recommendations for utilities and the PV industry are:

- Provide accurate information on performance, cost, and value of ZEHs. This information is necessary for stakeholders to assess their support for ZEH activities.
- Conduct analyses of peak demand, time-of-use rates, and time-of-use net metering. Analyses are needed to determine how PV can be used to best address a utility's peak period. Time-of-use rates and net metering can be designed to add PV value to the buyer and simultaneously help the utility address peak load problems.
- Engage builders in discussions on ZEHs and provide educational materials.
- Develop case studies and conduct workshops and seminars to engage a broad audience of builders. Identify their specific needs and concerns and address their needs and concerns in PV programs.
- Complete studies that quantify the utility value of ZEHs, ZEBs, and ZPCs. SEPA recommends conducting a value analysis to examine the usefulness of ZEBs, time-of-use rates, and time-of-use net metering as tools for addressing peaks. This analysis should also include strategies for maximizing the benefits of ZEBs.
- Work with builders, owners, and architects in the custom-home market to design and demonstrate new designs and technologies that are not yet accepted by production builders.
- Collaborate nationally to develop and promote the best-possible designs and technologies that are not climate-specific.
- Begin to develop ZEH designs for the residential retrofit market and the small commercial market. Both markets are immense and both are almost completely untapped.

Case studies that document projects in which stakeholders benefited from ZEHs would help to communicate benefits. Case studies should demonstrate the diverse applications of ZEBs and include examples from different regions of the country, with varying levels of support from utilities.

A package is needed to educate stakeholders about ZEBs. A series of regional workshops targeting utilities would effectively communicate this information while providing a forum for discussion and an opportunity to survey utilities on ZEB issues.

Some of the more important recommendations pertaining to specific technologies or technology areas include:

- Work with manufacturers to develop and implement reliable, low-maintenance solar domestic hot water systems.
- Develop HVAC designs optimized for specific climate zones.

- Evaluate and demonstrate geothermal heat pumps, two-stage evaporative cooling, and other innovative HVAC technologies in ZEBs.
- Develop and promote energy-efficient lighting solutions, with emphasis on fluorescent technologies.
- Locate and implement the most efficient appliances.
- Collaborate with others to develop, test, and introduce an ultrasonic clothes dryer.

3.1.8 PV Applications and Mounting Strategies

PV systems are being used in more and more applications with a wider variety of mounting schemes. The mounting schemes for PV include:

- Ground mounted
    - Fixed south or fixed west for late-peaking utilities.
    - One-axis tracking.
    - Two axis tracking.
- Covered parking and carports – commercial and residential
    - Roof mounted carports (see Figure 5)
- Roof-mounted – single family and multi-family residential
    - Integral to the roof, providing total weather protection (BIPV).
    - Rack mounted on top of a normal roof, building applied.
- Roof-mounted – commercial and industrial
    - Flat mounted or tilted.
    - Non-penetrating, non-ballasted.
    - BIPV including curtain walls and atriums.
    - Roof jack or rack mounted.

Applications include but are not limited to:

- Residential retrofit and new construction.
- Commercial-sector retrofit and new construction.
- Industrial buildings and process energy supply.
- Utility-scale projects.
- Community buildings and structures.
- Off-grid residential.

- Niche-market applications such as:
    - Remote monitoring (flood, cameras, security, weather, etc.)
    - Communications
    - Water pumping
    - Street lighting and parking lot lighting
    - Off-grid lighting for parks
    - Commercial sector signage
    - Signage for transportation
    - Landscape lighting
    - Fence charging
    - Cathodic Protection

Each of these applications has attributes that add to the value of the PV system. Most of the niche-market applications are off-grid and cost-effective today. Many of these installations can be considerably less costly than using conventional utility power that requires trenching, conduit, long or difficult electrical runs, and additional transformers or metering. Ground-mounted arrays are easier to construct and easier to troubleshoot and repair, but take up valuable, sometimes expensive, land area.

The value of covered parking (a variation on ground-mounting that allows vehicles to park under the array in the shade) offers a good array mounting solution and allows premium parking. Some locations are able to charge an additional fee, for example $2 per day per space, for the ability to park in the shade, while others obtain the good public relations of allowing customers and employees to park in the shade. These types of structures are common in the southwest and using the unused roof space for energy generation creates additional value for the structure.

3.1.9 Utility Issues

Issues in PV deployment raised by utilities are:

- PV peak output often does not coincide exactly with a utility's peak period.
- PV is not reliable or predictable enough for utilities to rely on for large scale use.
- Islanding raises the safety implications of unexpected energized lines during an outage.
- Utility benefit/cost ratios are unacceptable.
- PV-generated energy leads to loss of sales and revenue.
- Distribution system benefits cannot be adequately quantified and proven.

Figure 5. A PV carport at CalExpo

Photo Credit: AstroPower

Our study found that PV can provide value and respond well to some of these utility perceived issues. Although the output of a south-facing PV system may not exactly match the utility peak period, the output of a PV system usually does occur within the peak period and the utility can benefit by deferring expensive peaking power plants when the PV system output is available. Reliability can be defined in two ways: the reliability of the PV system equipment, and the reliability of the weather. Most new equipment meets reliability standards required by utilities. Accurate weather monitoring and predictions enables scheduling PV system availability, much like a river hydro power plant.

The issue of islanding has been fully resolved with the safety requirements of IEEE 929 and IEEE 1547 (see *Interconnection* for more details). Inverters and interconnection equipment capable of meeting the strict IEEE criteria do provide safe and reliable operations when connected to a utility grid. Further details on islanding and interconnection will be covered in the *Interconnection* Section below.

The last three issues — cost/benefit ratios, lost revenue, and distributed generation benefits — are being resolved as the proper values of distributed generation and customer-sited generation are identified, and the value of on-peak generation from a PV system is acknowledged. Both homeowners and utilities can benefit with time-of-use net metering (described in the *Net Metering* Section), which values the electricity produced during the peak period higher than that produced during off-peak times. This would encourage homeowners to orient their systems to provide the highest value electricity and helps utilities address their peak demand.

Interconnection

Interconnection is the term used for the connection of a PV system with the local utility grid. Interconnection involves both technical aspects and non-technical aspects. Technical aspects are related to the ability of the inverter to connect to the utility grid in a manner that will not disrupt the integrity of the grid, and do so in a manner that is safe for utility personnel and equipment. Non-technical aspects of interconnection include:

- A possible requirement to conduct an engineering study to determine if the inverter can be safely connected at the specific location.
- A possible requirement for an interconnection agreement with the utility.
- Local permits, approvals, or inspections.
- Possible fees or standby charges.
- Insurance.
- Property and local tax issues.
- Seismic considerations in earthquake areas.

A customer's ability to interconnect a PV system to the local utility grid is controlled by state and/or local electric utility interconnection rules and local permitting procedures. Unfortunately, these requirements vary widely, are somewhat dependent on the size and location of the PV system, and may therefore be mysterious to inverter manufacturers or PV contractors. It is not economically prudent for a manufacturer to have a special inverter design to comply with every jurisdiction's interconnection requirements.

Fortunately, there have been several activities related to interconnection standardization of small- to medium-sized distributed generation sources underway for several years:

- In January 2000, the Institute of Electrical and Electronic Engineers (IEEE) Standards Board passed IEEE 929-2000, "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems." This document is the result of a substantial collaborative effort by utility engineers, PV manufacturers, and other stakeholders. It addresses interconnection issues for small PV systems nationwide (specifically less than 10 kW_{ac}, but the document describes criteria for up to 250 kW_{ac}).
- The development of IEEE 929-2000 was coordinated with a parallel effort within Underwriters Laboratories (UL) to establish test procedures certifying that the requirements of IEEE 929-2000 are met.
- In May 1999, UL 1741, "Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems," was released, and this document has been updated several times since.
- The largest effort for interconnection of distributed generation was the establishment of the IEEE 1547 "Standard for Interconnecting Distributed Resources with Electric Power Systems." This effort started in April 1999 and the IEEE Standards Board approved IEEE 1547 on June 12, 2003.

Safety for the utility line worker, generation and utility equipment, and the customer was the primary concern throughout the development of these interconnection standards. More information on this valuable effort can be obtained at: http://grouper.ieee.org/groups/scc21/1547. For purchase of these documents, see http://shop.ieee.org/store/.

The establishment of IEEE 929-2000 and the recent IEEE 1547 gives utilities a quality and safety assurance that a PV system will operate safely and will not harm the utility grid or personnel. Equipment that meets these standards provides the needed utility safety and operational requirements.

California is fortunate to have a wealth of information related to interconnection of PV systems including "California Interconnection Guidebook: A Guide to Interconnecting Customer-owned Electric Generation Equipment to the Electric Utility Distribution System Using California's Electric Rule 21." This is available from the Energy Commission at http://www.energy.ca.gov/reports/reports_500.html#500.

Net Metering

Net metering allows for the flow of electricity "sales" both to and from the customer's facility through a single, bidirectional meter. With net metering, electricity from the customer into the utility grid offsets electricity consumed at other times. In effect, the customer is using excess generation to offset electricity that would have been purchased at the retail rate. Under rules in California, 30 other states, and the District of Columbia, residential customers are eligible for net metering. In some states commercial and industrial customers are also eligible.

Net metering provides customers with financial benefits by allowing them to receive *retail rates* for any excess energy generated. In effect, the utility buys the excess generation at retail rates from a PV system, and sells this energy to other customers. The utility benefits because it does not need to produce power (usually at a very high peak period cost) during the time the customer's PV system is generating excess energy. With net metering, the utility does not need to implement an expensive buy-sell arrangement with the customer, as the conventional energy meter on the home or building will usually run backward during the excess-generation period. No additional billing or administrative changes are needed. A comprehensive listing of the states and utilities that allow net metering can be found at www.dsireusa.org.

Any metering approach that measures cumulative energy use over a billing period can be used to incorporate net metering. A bidirectional meter is not required. Other metering options include more sophisticated (but more expensive) electronic meters with dual registers, and various dual meters.

Highlights of net metering include:

- Net metering is a simple, easily administered, and an inexpensive method to encourage customers to invest in small-scale renewable energy facilities.
- Net metering avoids the need to replace existing meters (most of which are bidirectional and, therefore, capable of tracking net energy flows) with more expensive dual meters or dual-register meters.
- Net metering makes the most sense for small-scale applications, where the costs of additional metering are high relative to the value of the energy being exported to the utility system.

- Net metering increases the amount of revenue that utilities and other energy service providers lose when their customers self-generate. The incremental revenue loss depends on the size of the customer generating facility, the customer's pattern of electricity use, the difference between retail and wholesale (or "avoided cost" prices), and other factors.

Most states limit net metering eligibility to certain technologies, usually solar and wind, and sometimes other renewables. Most states also limit eligibility to systems in specified size ranges.

Some states have capped the total number of net metering customers, or, more commonly, the total amount of generating capacity eligible for net metering. Usually these laws extend eligibility on a first-come, first-served basis to some percentage of the utility's peak demand.

3.1.10 Benefits of PV (SEPA 2003)

PV electricity differs in crucial ways from traditional grid electricity. The generation of PV electricity is clean, quiet, and emissions-free. It relies on an indigenous fuel (the sun) that is safe, inexhaustible, and ubiquitous. As a modular distributed generation resource, PV mitigates the risks and adverse impacts associated with building, owning, and operating large central generation capacity. As a peak-producing energy resource (in most locations), PV produces the highest-value electricity.

The attributes of PV enable it to increase energy supply and provide other positive value to utilities when any of the following applications are desired:

- Peak Production — in most locations and for many utility load shapes, grid-connected PV produces power during times of peak demand when the grid is under the most strain and electricity is the most expensive. When peak load is reduced, the utility and all electricity customers reap the benefits. Commercial facilities can achieve peak-period demand reduction with PV. If such facilities are sufficiently large to be demand metered, monthly demand charges can be reduced.

- Off-Grid Power — PV is the lowest-cost energy source for many off-grid applications ranging from vacation cabins and telecommunications to street signs and water pumping. PV can also provide portable power, such as for mobile highway signs, mobile generators, or even laptop computers. Equipment manufacturers are finding new, cost-effective applications for off-grid PV, increasing competitiveness in their market segment.

- Emissions-Free Power — PV systems produce electricity cleanly and quietly and are a viable source of energy in most situations where these attributes are valued, such as in national, state, or local parks, where power may be needed but polluting generation is not an option. As concerns about global climate change, carbon-free energy resources become increasingly important. Utilities and companies seeking to meet emission reduction targets can benefit from PV. The PV industry can encourage local policymakers to quantify the value of emissions offsets, thereby improving the economic competitiveness of PV.

- Reliability — PV systems can contribute to grid stability by reducing strain on the transmission and distribution system and by providing voltage support. PV systems with batteries can provide backup power in the event of a power outage, whether caused by a grid failure, ice storm, or hurricane. PV systems are durable and can last for 20 to 30 years or more. Companies and businesses with a need for reliable power can install PV systems with batteries to supplement grid electricity while the grid is operating, and take over when the grid is not operating. A battery system can also improve the peak load reduction capability of PV by dispatching power when needed.
- Worldwide Development — PV is well-suited to meet the growing demand for power in transitioning economies. As an essentially infinite resource that is available everywhere, it can provide the basis for development in countries lacking other energy resources. PV is a growing business in developed countries, and the United States must take action to remain competitive in international markets. These market segments are large and promising. Some transitioning economies have developed local financing tools that are effective in supporting the market for PV.

The untapped market for PV applications is extensive and can provide benefits to a wide range of stakeholders:

- The utility benefits from the peak-reduction capability of PV and from its ability to defer transmission and distribution system upgrades. This value has been estimated at more than \$1,000 per kW_{ptc} (Herig and McCabe 2002; Barker and Lewandowski 2002[8]). This benefit is especially important—and increases in value—in cases where transmission or distribution is constrained. Emission reductions also provide tangible positive value.
- The community benefits from reduced emissions of SO_2 and NO_x, allowing it to meet air quality targets as well as reduced emissions of mercury and of greenhouse gases. The value of the SO_2 and NO_x emission reductions ranges from \$85[9] to \$660[10] per kW_{ac}. Depending on the cost of carbon, the avoided greenhouse gas emissions could be worth \$300 per kW_{ac} or more.[11]
- The residential consumer benefits from: (1) lower electricity bills; (2) reduced impact of electricity price increases; and (3) increased home resale value (Nevin and Watson

8. This report cites value of 2 to 4 cents/kWh. At an assumed lifetime generation of 30,000 kWh per kW, this is a value of \$600 to \$1200/kW.

9. This estimate uses average emission rates from the electricity sector, from the Energy Information Administration's *Electric Power Annual 1999 (Volume 2),* combined with average market clearing prices of \$200 per ton of SO_2 and \$1000 per ton of NOx.

10. Based on the National Park Service assignment of emission costs, post-September 1997, as listed in "Electrifying Pinnacles," U.S. DOE/NREL/FEMP publication *DOE/GO-10098-543*, October 1998.

11. At an average United States grid factor of .67 tons CO_2 per MWh, a cost of \$15/ton CO_2 (roughly \$4 per ton of carbon) and lifetime production of 30,000 kWh per kW, the value of the CO_2 equals \$300 per kW.

1998).[12] For many consumers, the benefits of self-reliance, taking positive action to protect the environment, or interest in advanced technology have a non-quantifiable value that may be worth more than the "dollar" investment that PV requires.

- Commercial and industrial consumers also benefit from photovoltaic systems. Whether it is directly, through reduced peak power consumption or lower emissions, or indirectly, from the "green" visibility value of installed PV, these consumers can also reap both tangible and intangible value from PV.

Impact of Utility Rate Structures on the Benefits of PV (SEPA 2003)

Time-of-Use Pricing. Time-of-use (TOU) pricing can greatly improve both the economics of PV and the utility's load profile. Rates are grouped into predetermined peak and off-peak periods, sometimes including shoulder-peak periods as well. In California, the peak periods of greatest concern occur on summer afternoons when air-conditioning loads are greatest. Electricity prices on the spot market are greatest during these periods and TOU rates are structured accordingly. PV systems produce power during summer peak periods. As a result, a TOU rate simultaneously: (1) allows the utility to reduce its peak-period energy costs; and (2) when a facility is TOU metered, allows a PV system to provide the greatest benefit to the facility owner. TOU rates are common for large commercial-sector facilities and are sometimes offered as an option for other customer classes including residential customers. However, some utilities have found it technically difficult to employ net metering in conjunction with time-of-use pricing.

Real-Time Pricing. Real-time pricing is a concept that is not yet utilized for the residential and commercial markets. It is similar to time-of-use pricing, except that the rates are determined in real time (or a short time in advance) using market pricing mechanisms. Some appliances, machines, and industrial facilities can be programmed to slow or stop operation during temporary high power rates.

Fixed Cost vs. Usage-Based Costs. A rate structure with minimal or no fixed cost encourages conservation and customer-sited power. In this case, a customer's bill is proportional to energy use and, in some cases, peak demand for electricity. A rate structure with high fixed costs (such as connection or standby fees that some utilities charge independent of customer power usage) and lower rates per kilowatt-hour, provides less incentive to conserve. This adversely impacts PV system economics.

Tiered Rates. A rate structure with escalating cost tiers based on usage encourages conservation and use of PV. Studies have shown that a tiered rate structure can have a positive effect on the economics of PV equal to the effect of a $\$3{,}000/kW_{ptc}$ rebate (Herig and Hoff 2002). This assumes that the home or facility has sufficient electrical usage to be billed in the higher-cost tiers.

Demand Rates. Demand charges are a component of a utility bill based on peak demand required by a facility over a month or a year, usually applied to commercial and industrial

12. Authors found that home resale value increases $20 for every $1 reduction in annual utlity bills. At 4.10/kWh and 1200 kWh/kW per year, this is $2400/kW. Additionally, some homebuyers may be willing to pay more for a home with PV due to its environmental attributes.

customers. If the peak demand is mid-day, south facing PV can reduce the peak demand charge. The correlation between PV system production and a facility's peak demand depends on the facility's load profile, which may or may not resemble the utility's load profile, and the orientation of the PV system.[13] Orienting the PV system to match peak demand will reduce a facility's peak demand for electricity while slightly reducing the amount of electricity produced by the PV system. Short-term energy storage (e.g. batteries) can help achieve greater savings regardless of the weather, stabilizing the PV output to provide consistent demand reduction across the entire peak period as well as providing backup power.

Additional Benefits of PV (SCG 2003)

PV provides more than just electricity. An overview of the environmental, economical, and social benefits of PV includes the following:

- **Job Creation —** According to the Renewable Energy Policy Project (REPP), for every megawatt of PV, 35.5 jobs are created in manufacturing, installation, servicing, sales, and marketing.
- **Environmental —** PV is a pollution-free source of electricity that can be sited close to the demand, which limits the need for additional transmission and distribution (T&D) power lines. PV can play a critical role in mitigating the threat of climate change.
- **Reliability —** PV systems last, on average, more than 25 years and require minimal maintenance.
- **Economic —** PV provides fixed-cost electricity for the life of the system. PV systems are ideally suited for peak-shaving applications as they produce the greatest amount of electricity when demand and pricing are the highest. This peak reduction can provide valuable T&D system benefits for the local utility.
- **Flexibility —** PV systems are modular and expandable depending on demand and, if utility controlled, can be sited as needed to support utility T&D requirements.
- **Energy Security —** PV reduces reliance on coal, natural gas, and other price-volatile energy sources. PV reduces susceptibility to energy shortages, market manipulations, and other disruptions. PV reduces stress on the existing grid.
- **Public Health —** PV helps to ease pollution-related problems. In addition to being pollution-free, PV operation is also quiet and does not use water.

The value of PV technology to the nation should increase dramatically over time as the cumulative base of installed systems grows and the cost of PV installations declines. Such volume increases are expected to reduce system costs. Beyond this, the economic value will also be enhanced to the degree that public policy (national, regional, or state policy) encourages the monetization of environmental attributes through trading mechanisms or other means. These

13. For more information, see a list of relevant studies compiled by Richard Perez (SUNY-Albany) at: http://www.asrc.cestm.albany.edu/perez/PVLoadMatching/more_percent20papers.htm

environmentally derived economic benefits will augment the other system-oriented benefits of PV.

3.1.11 The Cost of PV

This costs section presents limited data on the actual costs of PV systems. Potential cost reductions and increases in value that can help to improve the economics of PV are presented.

PV system costs have been declining for three decades and will continue to decline, with temporary deviations due to constrained supply from time to time. The SEPA TEAM-UP project and recent SMUD experience provide cost figures for comparison. In the TEAM-UP period of 1996 through 2000, the total installed costs of large commercial-sized PV systems (greater than 70 kW_{ptc}) ranged from \$6,000/kW_{ptc} up to \$11,000/kW_{ptc}. Total installed residential-sized PV system (1 to 5 kW_{ptc} in size) costs ranged from \$8,000 to \$11,000/kW_{ptc} for the same period. An analysis of the actual partial costs (see note below) of 68 SMUD PV installations on residential retrofit homes for the year 2002, under its PV Pioneer program (not including SMUD transaction and management costs), revealed an average installed cost of \$6,540/kW_{ptc} broken down in the following data:[14]

- Module costs (including panelization) averaged \$3.71/W (\$3,710/kW_{ptc}) with a range of \$3.03 to \$4.53/W_{ptc} for the three manufacturers involved.
- Inverter costs (including BOS costs) averaged \$1.19/W_{ptc} (\$1,190/kW_{ptc}) with a range of \$0.73 to \$1.54/W_{ptc} for at least two manufacturers involved.
- Installation costs (including purchased materials) \$1.64/W_{ptc} (\$1,650/kW_{ptc}) with a range of \$1.57 to \$2.17/W_{ptc} for several installers involved.

There were 68 installations that ranged from 1 kW_{ptc} to 5 kW_{ptc} with the majority (66%) of the systems in the 1.8 to 2.9 kW_{ptc} range.

A 2003 California Energy Commission report (Energy Commission 2003) estimates that the levelized cost of energy for photovoltaic systems will be nearly cost competitive (without rebates) by 2017. By late 2005, it was expected that a residential customer in a high insolation region would be able to install a 3 kW_{ptc} photovoltaic system that generates electricity at about 23 cents/kWh (without incentives). By 2017, it is estimated that these costs will drop to approximately 12.6 cents/kWh.

The Costs of PV and the Potential for Cost Reductions (SEPA 2003)

PV-generated electricity will not usually compete against conventionally generated electricity on generation cost alone. It is often noted that PV power costs several times more than conventional fossil fuel power, with generation costs cited as low as 3 cents/kWh compared to possibly 30 cents/kWh for PV generated electricity. However, PV generates electricity at the point of use, so it should be properly compared to the retail cost of electricity, which averages about 8 to 12 cents/kWh for residential customers in the United States. Additionally, this

14. Note: SMUD transaction costs, project management, interconnection, contract, or overhead costs are *not* included. The reported costs are only equipment and installation costs.

comparison ignores the true cost of summer peak-period electricity and the cost of T&D needed to deliver conventionally generated electricity to the end user. During peak demand times, delivered energy costs from conventional sources may reach 25 cents/kWh or higher in some areas.

The cost of conventionally generated power also fails to account for externalities, such as the adverse health impacts attributable to air pollution from fossil fuel generation. Research continues to quantify these externalities and provides a solid rationale for incentives. If the calculated value of the externalities exceeds the difference between PV and fossil-fuel power, then an objective analysis supports the deployment of PV. PV *should* receive recognition for its full value through the valuation of externalities as is supported in several sections of this report. In one case, the National Park Service (NPS) has assigned defined values to emissions that can be used in purchasing decisions.[15]

Some states assign costs to emissions during the planning process for power plants. The NPS showed creativity and logic in applying this methodology to off-grid power generation. States, counties, and municipalities can apply these values to new loads that would normally use grid power. Opportunities for evaluation of these values include a line extension to a new facility, or supplying power to streetlights and traffic lights.[16] When an expensive trench-copper-wire-conduit run may be required to connect to the grid, PV provides additional values.

Some externalities, such as the preservation of resources for future generations, may be harder to value but may still be considered in a qualitative manner.

BIPV offers value as a structural and aesthetic building component. For example, commercial architects often design curtain walls of glass windows, extending around the perimeter of a building, from top to bottom.[17] Glass curtain walls or façades of premium materials such as granite or marble may cost $50 or more per square foot. BIPV costs about $125 per square foot (McCabe). Thus, when a premium façade is replaced with BIPV, the effective cost of the PV is only $75 per square foot;[18] $50 of the cost can be attributed to its value as a building component. Interest in green buildings is accelerating rapidly and the U.S. Green Building Council (www.usgbc.org) and others are working on further quantifying these benefits.

Even with all of these additional values, the cost of grid-connected PV systems must be reduced to sustain market growth. PV manufacturers cannot sell product at a loss, and PV contractors will not work at a loss. The PV industry cannot rely on an unending stream of incentive funding from government agencies and utilities. It is likely that grid electricity costs will increase, but they are unlikely to increase in the short term to the point where PV systems, at today's prices,

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15. These values were to increase after September 1997 to $.85/lb. SO_2, $3.75/lb. NOx, and $14/ton CO_2.

16. For loads such as streetlights, the costs of trenching and metering may also be significant, making PV more cost-effective relative to a grid extension.

17. Generally, *curtain walls* are non-load-bearing walls enclosing a building.

18. PV can generate about 10 watts per square foot.

will become economically attractive.[19] Increasing electricity rates in *nominal* dollars can make PV a much more viable option if financing is provided.[20] Without valuation of all PV attributes, PV needs to provide power at a cost of less than 12 cents/kWh in order to compete directly on price against today's grid power. For PV to compete in densely populated regions such as California and the Northeast, a system would need to be installed for about \$3,000/kW_{ptc}.[21] For residential retrofit applications, modules currently cost about \$4,000/kW_{ptc}; inverters, \$1,000/kW_{ptc}; and other hardware, labor, and fees, \$3,000/kW_{ptc}. (Current installed costs for commercial-sector projects are under \$7,000/kW_{ptc} in California.)

Estimates of future costs are commonly based on the *progress ratio*. Research has shown that, when cumulative PV production has doubled from a given level, the new cost is about 82% of the old cost. This number is the progress ratio. A smaller progress ratio indicates costs are decreasing at a more rapid rate. At an annual growth rate of 20% and a progress ratio of 82%, costs are reduced by about 5% per year.

Installers believe that they have reduced costs as much as possible and that future cost reductions are dependent on module costs coming down. Some module manufacturers note that labor installation costs in the United States are much higher than costs in Japan or Germany and that these costs must come down. Inverters are often cited as a key area needing improvement in both cost and reliability, but significant progress has been seen in this area in recent years. No one sector can make PV fully competitive by itself. If module costs are reduced with a progress ratio of 82%, but labor and balance-of-system remain constant, then by the time 25 GW of PV has been installed worldwide (more than 10 times the current total), residential systems will cost \$5,650/kW_{ptc}, down from \$8,000/kW_{ptc} today. A similar situation could occur if balance-of-system and labor costs are reduced but material cost constraints slow the progress of module cost reductions. If, on the other hand, the *whole* system can advance at an 82% progress ratio, installed cost will be \$3,380/kW_{ptc} by the time 25 GW_{ptc} have been installed. A cumulative total of 25 GW_{ptc} will be installed by 2011 if the average annual growth rate is 32%, 2016 if it is 16%, or 2023 if it is 8%.

Module cost reductions will be obtained through increased economies of production (larger, full operation factories), competition among manufacturers, and the emergence of new manufacturing techniques and technologies. The PV industry must continue to: (1) increase the overall efficiency of PV systems; (2) innovate constantly; and (3) increase standardization and

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19. A CO_2 cost of \$100/ton would only raise the cost of United States grid power by about 7 cents/kWh, based on an average emissions rate of .67 tons per MWh.

20. The retail costs of electricity in California increased at an average annual rate of 6% between 1970 and 2001, according to Solar Depot. If similar growth is assumed for the future, the economics of PV are greatly improved.

21. The figure of \$3 per watt is based on the figure of 1200 kWh per year per peak watt, with system degradation of .5% per year, 30-year system lifetime, and nominal system O&M expenses of 1 cent per kWh. It assumes 100% down payment and no cost of money. Actual O&M expenses may be higher; a figure of 1 cent/kWh is on the order of \$1,000 lifetime for a 3 to 4 kW PV system.

interchangeability where possible. Manufacturers must develop and market systems that are easier and faster to install to reduce labor costs.

Very large installations of PV have achieved installed costs of \$6,000/kW_{ptc} or less. These are often behind-the-meter installations at large commercial or institutional facilities, combining the benefits of distributed generation with those of economies of scale. PV can provide an economic benefit to such facilities by reducing peak demand and by reducing power purchased.

The equivalent cost of electricity from a PV system for various prices can be seen in Figure 6. The threshold price for PV systems is defined as the price when PV becomes a competitive option for a large number of residential and commercial applications. SEPA believes that the threshold price for PV is near the \$3,000/kW_{ptc} level, based on total costs, after any incentives or rebates. The threshold price can exceed \$3,000/kW_{ptc} if the building is located in utility areas with high electricity rates, high daytime demand charges, or TOU pricing (SCG 2003).

Table 1. Cost of PV by Installed Kilowatt and Kilowatt-hour (SCG 2003).

	EQUIVALENT COST PER KILOWATT-HOUR	
COST PER INSTALLED kW_{ptc}	**RESIDENTIAL**	**COMMERCIAL/INDUSTRIAL**
\$8,000	\$0.37	\$0.25
\$6,000	\$0.27	\$0.18
\$4,000	\$0.18	\$0.12
\$3,000	\$0.14	\$0.09
\$2,000	\$0.09	\$0.06
\$1,000	\$0.05	\$0.03

**Assumes a 15-year home equity loan at 7% interest (residential), including federal tax deductions for an average household earning \$80,000 year, or a 7-year loan at 6% interest (commercial/industrial); a system producing 1,800 kilowatt-hours per year per peak watt; a 25-year system life; and an annual degradation of 1%. Does not include tax credits.*

Source: Solar Electric Power Association.

It should be noted in Table 1 that the cost of commercial systems is lower due to several factors. When compared to a 2 to 4 kW_{ptc} PV system installation, the transaction costs (sales, design, permitting, and related contracts) of a commercial system are less on a per kilowatt basis, and also equipment and installation costs are reduced due to the economies of scale, optimized labor usage (field labor forces and utilization, and redundant tasks for many installation steps).

3.1.12 Marketing and Outreach

The PV industry and electric utilities have had limited success in marketing PV to their customers and other stakeholders. For the PV industry, this includes residential, commercial, and utility customers. Utilities must sell PV to upper management or governing boards in addition to their customers. In the context of PV being a high-cost purchase, it has been difficult to communicate the value of PV and share factual information on the costs and value of PV.

PV is viewed very favorably by the public but this does not always translate to actual sales of PV or support for green pricing and other PV programs. A great deal of market research has been conducted by NREL to determine the demand for green power. While very informative, research tends to over-predict participation in green pricing programs, indicating that a larger

group of consumers are willing to pay a premium for green power than will actually pay when the program begins. Although there have been many reports of programs exceeding expectations, other programs have failed to achieve the results predicted by early market research. Utilities planning new programs should keep this in mind and plan conservatively. To the customer, PV technology converts solar energy into electrical energy, supplying their home with electricity. PV can provide power during a utility outage with an optional battery back-up. Although technologists focus on the efficiency of the PV cells, the size of the module, and mounting and building-integration options, the customer sees it as an appliance that provides clean, quiet, renewable energy as a substitute for a portion, or all of the electrical service from a utility.

Marketing Elements

There are four key elements for marketing new products: product, price, distribution, and promotion. The product, in this case PV, must provide a favorable cost/value picture to the purchaser, recognizing that some purchase decisions do have emotional content that is difficult to quantify. The distribution channels must make the customer aware of the product and provide ease of purchasing. Finally, the product must be promoted through advertisements, word of mouth, etc. These four factors must be combined for a successful marketing campaign.

Product

The product in question is PV, and it is available in many forms. It is available for applications on buildings, some substitute for building products, and for applications in rural, urban, and settings in between. Aesthetic concerns are addressed with solar products that look like roofing materials, or with out-of-sight installations. Additional BIPV options will expand the specification of PV by architects and the application in neighborhoods with historic or design restrictions.

Price (and Value)

Price is a key issue with the product but the benefits it provides can significantly offset its high cost. PV-generated power still costs more than conventionally generated grid power. Consequently, all participants in the PV market must identify opportunities for cost reductions (e.g., in materials, system components, installation methods, etc.) and set realistic targets for future cost reductions.

The value of PV for the end customer is greatly dependent on available incentives and the benefits that the customer identifies with the PV investment. For positive value, the customer must acquire from PV greater total benefit than its net price. This is difficult because many of the benefits associated with PV are difficult to quantify and vary among people and businesses. Additionally, incentives vary from state to state, and even regionally within a state. Utilities may not be eligible for incentives, but may be able to sell the PV-produced power either to their customers or to a bulk green power purchaser. When setting the price and communicating value, it is important to understand what incentives are available and how they can be used to make the price more acceptable to the consumer.

The Public Benefit Funds in 26 states offer an exceptional opportunity that may or may not be repeated and continued in the future. Employing these funds to make major investments in PV can be useful for early adopters and move the technology along the "learning curve." Other incentives, such as Oregon's Business Energy Tax Credit, can help move PV technology into the marketplace. The PV Industry can help by providing clear information to government policymakers about the size and duration of incentives that are necessary to drive down the cost/volume curve to a sustainable price point.

Utilities receive grid support from PV, since it is a distributed generation technology, and utilities also receive the benefit of good publicity from utility-owned PV systems. The general public benefits from the cleaner air resulting from the emissions offset by the use of PV, and by the economic growth a new industry brings to the community. These are just a few examples of the benefits associated with PV. More information on the benefits of PV can be found in Section 4. When developing a marketing strategy, determine the audience, the benefits relevant to that audience, and how to communicate those benefits to them.

The environmental benefits, the "coolness" factor of owning a PV system, and the electricity savings all contribute to a customer's decision to purchase a PV system. People do not always purchase the cheapest product, and PV could be compared to a luxury item, such as a high-end television or automobile.

PV provides a diverse range of benefits to all market participants. Some of these benefits can be quantified and should be highlighted where possible. For example, the value of PV to enable utilities to defer T&D investments may be worth $1,000/kW$_{ac}$ or more; the value of emissions offset may be worth another $1,000/kW$_{ac}$. (SEPA 2003) It is critical that the industry communicate the benefits of green power produced by PV compared to traditional electricity generation:

- Greenhouse gas emissions/pollution.
- Provides peak power.
- As a distributed resource it reduces transmission losses.
- No moving parts/silent.
- Energy security for the nation.
- Energy independence for the end user (with battery back-up).

New niche applications have helped to make PV as successful as it is today. In addition, many communities have shown increasing interest in PV. It is critical to leverage the existing momentum of these early applications and community interest by increasing public outreach and offering incentives (SEPA 2003).

Many customers do not realize the additional value of PV; therefore, it is a harder sell for utilities and the PV industry to convince customers to purchase a PV system rather than relying on the electricity grid. This is why incentives and education are critical to building the market.

Solar Equipment Distribution

The PV distribution and sales infrastructure is weak in most regions. Customers are not knowledgeable about PV, do not know where to go to purchase it, and, if they have it, do not always know who to call for maintenance. Relationships between manufacturers, wholesalers, and retailers are needed for a mature industry. As the infrastructure matures, the demand will grow, and vice versa. PV in high visibility locations, such as community facilities and schools, helps to raise awareness of the technology. Those who sell and install PV must make their services as visible as possible.

Installers and designers need better training and more experience to better support the infrastructure development. Utilities have the resources to train local installers and can help implement quality control measures. The TEAM-UP program required that all systems purchased with SEPA support meet certain technical standards to ensure performance and safety. Similar technical requirements could benefit a utility program and help minimize operation and maintenance costs. The North American Board of Certified Energy Practitioners (NABCEP) has implemented a certification for installers, which is another important step toward infrastructure development.[22]

Promotion

PV needs promotion. The value, price, and purchasing information need to be communicated for the end user to respond. This can be accomplished through mass marketing, targeted promotion, advertising, and word of mouth. Regardless of the strategy for communication, it is critical to the industry that the customer becomes more aware of PV. Different approaches to PV promotion may be used depending on the sector that is being targeted. For example, a utility may use a mass mailing to its customers to promote its green pricing program. However, to sell green power to wholesale power purchasers, a utility would take a much more direct approach.

Successful PV marketing requires that the utility know its target audience, the benefits unique to that audience, the impact of incentives on the purchase decision, and the available infrastructure to support PV.

Many PV demonstration projects exist today with an increasing number of consumers aware that PV power is available; however, it is still not considered mainstream. In order to bring PV into the mainstream and achieve a transition to a clean energy future, industry will require a sustained and continuous increase in the amount of visible PV deployed over many years.

Care must be taken to communicate accurately. For example, many customers are confused, assuming a PV system will make a home or business independent of the utility during a black out, unaware that this requires an inverter that is designed to operate in combination with an additional-cost battery back-up.

22. North American Board of Certified Energy Practitioners, http://www.nabcep.org/

Strategies and Tools to Market PV

Utilities have used a variety of mechanisms to promote PV to their customers. Bill stuffers, the traditional tool for utilities, have been used to promote green-pricing programs but there are many other options for promoting PV. The mechanisms at this stage in the market must include an educational component. The majority of the general public, lacking the proper understanding about PV, will continue to be hesitant to invest capital. Therefore, all strategies to market PV must include an educational component as well as a sales component.

PV programs have used high-visibility PV installations, such as the one located at the new fire station in Roseville, California, to bring attention to the program. Utilities receive many benefits from this strategy: An improved image for their commitment to green power; raised awareness and support of their PV program; and use of the electricity generated by the PV system. Utilities have installed PV at local schools, community buildings, and parks to generate support through the community.

Local events, fairs, and festivals offer excellent opportunities to put PV to work in the public eye. PV can be used to power outdoor lights, microphones, and other electronic devices. Not only is the event touted as "green," but the public learns about PV and the utility benefits. PV is an excellent replacement for portable generators that pollute and are noisy.

Other strategies to promote PV include promotional programs, TV, radio, newspaper advertisements and publicity, and participation in local events.

3.2 PV Markets

This section addresses the PV markets regionally and by application, and concludes with market growth strategies. The California market and, more broadly, the United States market, are the subject of this report. The broader United States market has been strongly influenced by California, but other states—including Arizona, Massachusetts, New Jersey, and Florida—have also been significant in expanding the market. The California market is by far the largest and most significant in the nation and includes on- and off-grid applications for PV. California's market has been influenced by high electricity rates, the energy crisis that spanned 2000 and 2001, and an abundant solar resource.

The grid-tied market has been difficult to penetrate because of the low cost of grid electricity in the United States compared to the cost of PV. With rebates and incentives, and the growing focus on distributed generation, PV is increasingly seen as a viable energy technology for grid-connected applications. Off-grid applications are successful PV applications because PV is cost-competitive with other alternatives, and requires minimal maintenance and no fuel. Recently, these applications have expanded to include urban applications such as street and sign lighting and highway call boxes.

Regardless of the specific market focus, there are several factors that strongly influence the ability of PV to become a viable energy resource. These can be incorporated into any PV deployment strategy and will help move PV technology toward full commercialization.

3.2.1 United States Market

The PV market in the United States has experienced strong growth since the mid-1990s. In Section 3.1.2 the report touched on the fact that the United States market is the third largest in the world, behind the Japanese and German markets (Sugano 2003). The nation is behind largely because of low electricity rates and strong, nationwide incentives and programs in Japan and Germany (World PV Growth shown in Figure 6). Even as the third largest market, the United States has experienced a growth rate of 15 to 20% (U.S. DOE 2002), with the 2002 market topping 57 megawatts (MW_{stc}).[23] Despite this growth, the nation's share of the global PV market is shrinking.

The United States PV market is fragmented because the nation has diverse utility business practices, widely varying solar resources, and different state public polices for interconnection standards, net-metering laws, and incentives. TEAM-UP and the Million Solar Roofs (MSR) Initiative are the only national programs that have focused on stimulating the PV market. The SEPA TEAM-UP PV deployment program ended in 2000 and the current MSR Initiative has been scaled back due to reduced funding in the past years. TEAM-UP focused on hardware deployment and utility PV involvement. More than 7 megawatts of PV were installed as part of the TEAM-UP program. The MSR Initiative is a substantial grassroots effort to build PV infrastructure and educate stakeholders about PV with the goal of having 1 million PV or solar thermal rooftop systems installed by 2010. More than 60 partnerships have been formed through MSR, although tracking progress against the 1 million roofs goal has been difficult.

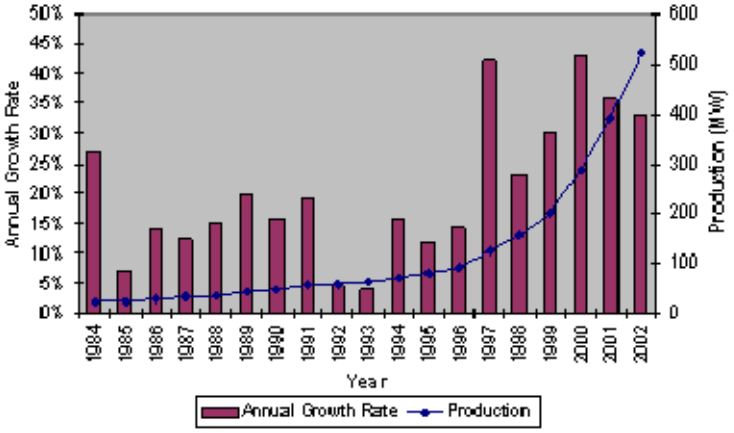

Figure 6. World PV growth 1984-2002

Source: Solar Electric Power Association.

Despite successful commercialization efforts, the cost of PV remains high. Those areas with significant buy-downs have a much greater market for PV than those states and localities without buy-down programs. Projects sometimes have faced difficulties obtaining financing and lending institutions are hesitant to finance solar projects because of their unfamiliarity with

23. From "Fast Solar Energy Facts: Solar Energy USA," Solar Buzz website, http://www.solarbuzz.com/FastFactsUSA.htm

the technology. Insurers are also wary to cover solar projects because their potential risks are undocumented.

3.2.2 California Markets

Energy Situation/Background

There is a large PV market in the State of California, particularly in Sacramento and Los Angeles where the municipal utilities have implemented aggressive PV programs and incentives. Energy reliability, electricity cost concerns (as shown in Table 2), the availability of the state buy-down funds and incentives, and strong utility support for PV make California a prime region for PV deployment.

Table 2. California Average Retail Electricity Rates by Major Utility, 2001.

	LADWP	SMUD	Burbank	Glendale	Pasadena	PG&E	Edison	SDG&E
Residential	10.4	9.2	11.5	14.4	14.3	12.0	13.3	13.5
Small Commercial	10.8	10.5	11.3	15.9	14.8	16.8	17.8	14.2
Medium Commercial	9.6	9.5	11.9	13.5	14.3	14.1	15.0	11.0
Industrial	7.4	11.7	10.3	13.6	12.8	10.0	12.1	8.5
Agricultural	n/a	9.6	n/a	n/a	n/a	15.9	13.2	12.9

*Cents per kilowatt-hour.

Source: Solar Electric Power Association.

At the close of 2003, California had installed close to 60 MW_{ptc} of PV generation capacity (Energy Comission2003). Figure 7 shows that the California PV market is growing rapidly, with total installed capacity increasing dramatically from 2000 to 2003.

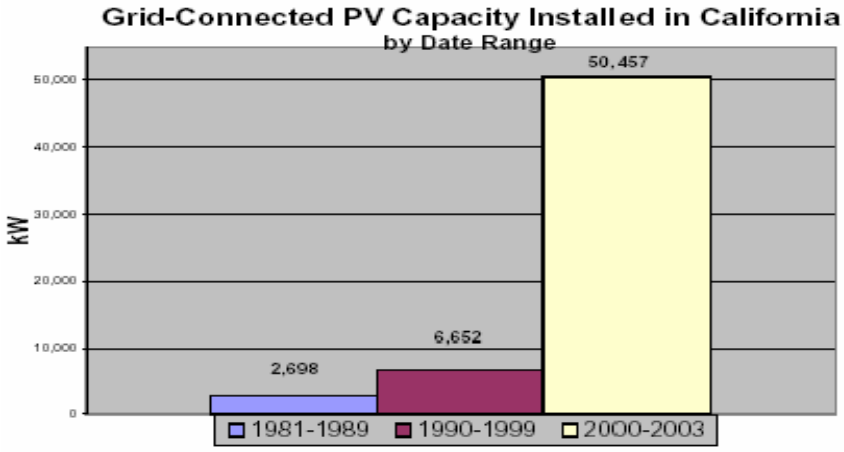

Figure 7. Grid-connected PV capacity installed in California

Source: Sustainable Conservation

One of the stimulants for this market growth was California's energy crisis in 2000 and 2001. Rolling blackouts and brownouts triggered many to question the reliability and stability of the electricity grid. People began seeking alternatives to utility-supplied electricity, and the PV industry saw a surge of sales immediately during this period and shortly after. Recent economic conditions have tempered this market, but the availability of buy-downs in California continues to fuel growth in the state. Without the rebates and incentives, the PV market in California would likely collapse or at least experience significant growth-rate decline.

Renewable Portfolio Standards

California has been one of the most aggressive states in promoting renewable energy, specifically PV. The legislature has established a renewable portfolio standard (RPS), requiring 20% of retail electric sales to be renewable by December 31, 2017, for California's investor-owned electric utilities (IOUs), and requiring renewable energy objectives for municipal utilities. Utilities must increase the renewables in their electricity mix by 1% per year until the RPS goal has been met.

The RPS law requires that each municipal utility implement and enforce a local RPS that "recognizes the Legislature's intent to encourage renewable resources, especially wind and photovoltaics, taking into consideration the effect on rates, reliability, financial resources and the goal of environmental improvement."

The governing board for municipal utilities in California must define the terms of its RPS and include the following in the definition:

- What qualifies as a renewable resource (e.g., whether or not to count large hydro).
- The percentage of the total energy resources that are to be renewable.
- How quickly they plan to meet that goal.

The three main IOUs in California—San Diego Gas and Electric, Pacific Gas and Electric, and Southern California Edison—all plan to meet the RPS much sooner than the 2017 deadline and are already showing significant progress (Energy Commission2003a).

A few people interviewed during this project expressed concern that green power for utility green-pricing programs cannot be counted towards an RPS. This may force utilities to choose between offering customers a green-pricing program and meeting their RPS.

The RPS is a significant step toward encouraging utility adoption of renewables; however, it does not include a mandate for PV, the most valuable and expensive of renewables. PV is the only renewable technology that closely matches the peak daytime load that many California utilities experience and is sited at the load, reducing T&D costs. Without a mandate for PV, many utilities will seek less expensive forms of renewable energy to meet the RPS.

Building Markets through Incentives

To develop markets, incentives are needed. Many of those interviewed during this study indicated that residential buyers respond well when PV payback is in the range of 7 to 10 years, and commercial buyers respond when PV payback is 4 to 6 years. State, community, and/or utility buy-downs or energy production incentives continue to be critical to reduce the effective cost of PV and to obtain the payback needed to increase customer acceptance and interest. The study results were very clear that these incentive programs must be long-term and multi-year, even if the amounts decline over time. Maintaining a program over several years (the needed continuity period) allows stakeholders to plan for long-term projects. In many cases, project development and implementation (purchase decisions, financing, permitting and approvals, etc.) may take two years or more. Incentives that abruptly change significantly in this time frame have limited ability to support real market decisions. Several of those interviewed commented on the disruptions to their businesses that were caused by gaps in the California rebate funding and abrupt changes in the program over time. They mentioned that they need federal, state, and local incentives to be stable (even if they decline over a known time period), funded properly, and available when promised. As a result of our interviews, the study also concluded that to effectively build PV markets all incentive programs should be structured to reward long-term PV system performance, not just installed capacity.

California Incentives for PV

To further the development of renewable technologies, the Energy Commission is providing funding for research programs, such as PIER, and for the Emerging Renewables Program (ERP), which provides a rebate for systems less than 30 kW_{ptc} installed by IOU customers.

In 1998, California Legislation AB1890 required IOUs to collect $450 million from their customers to support renewable technologies in California (Energy Commission 2003b). The ERP originally offered a rebate of $3/$W_{ptc}$ for PV systems, and provided rebates for other renewable technologies, providing a small impact on the emerging renewable technology market. In 2001 the ERP increased the rebate to $4.50/$W_{ptc}$, and saw a greater impact on the market. Currently the rebate is decreasing by $0.20/$W_{ptc}$ every six months, although in December 2003 the rebate decreased by an additional $0.40/$W_{ptc}$, and the resulting rebate as of January 1, 2004, was $3.20/$W_{ptc}$. Rebates from the ERP are only available to IOU customers.

The California Public Utilities Commission's (CPUC) Self-Gen Program provides a rebate for 50% of the installed PV system cost, to a limit of $4.50/$W_{ptc}$ for IOU customers who install PV systems 30 kW_{ptc} to 1.5 MW_{ptc}. As of 2004, California IOUs have only the ERP and Self-Gen programs as incentives to PV installations.

California's Franchise Tax Board offers a Solar Energy System Credit, a 15% income tax credit available to both residential and commercial entities to encourage private investment in PV and wind systems up to 200 kW_{ptc}.

More information about constantly changing rebates and incentives programs in California and other states is available from the Database of State Incentives for Renewable Energy (DSIRE) at www.dsireusa.org.

California Utility Incentives

Several utilities have implemented a variety of incentives to stimulate the demand for PV. Table 3 shows the California utilities with incentive programs. The California IOUs are implementing the ERP and Self-Gen programs, but have little other PV activity.

Much of the PV activities in California are tied to the municipal utilities, as shown in Figure 9. In addition to those shown below, San Francisco Public Utilities Commission (SFPUC), through the Hetch Hetchy Water Department, is implementing two PV deployment efforts. Reacting to rolling blackouts and soaring energy prices, in November 2001 the San Francisco voters passed the $100 million Solar Bond Initiative to fund solar generation, energy efficiency measures, and other renewable power sources for public buildings in San Francisco.

In September 2003, also part of the Solar Bond program, San Francisco's Department of Environment announced Generation Solar, a residential and commercial solar program to serve local residents and businesses. The program will provide at least 100 residential and commercial participants with turnkey PV installations, financing options, and accompanying energy-conservation measures.

Additionally, Roseville Electric has established an RPS target to have an energy mix with a minimum of 20% from renewable resources. Their strategy to meet the RPS objective is to

increase renewable resources in Roseville over the next five years by 5 MW_{ac}. Roseville Electric currently imports 99% of its power, with local generation supplying less than 1%. Roseville is proposing a 150 MW_{ac} Energy Park that will allow Roseville to produce 60 to 65% of its power locally. The Energy Park will include a least 1 MW of PV generation facility and along with natural gas fired conventional generation.

Table 3. Utility Incentive Programs in California
Source: The Database of State Incentives for Renewable Energy

Anaheim Public Utilities – PV Buydown Program • Incentive Type: Utility Rebate Program • Eligible Technologies: Photovoltaics • Applicable Sectors: Commercial, Residential • Rebate: \$5/W_{ptc} for residential; \$4.50/W_{ptc} or 50 percent of the system • Website: www.anaheim.net/utilities
Burbank Water & Power – Residential Solar Support • Incentive Type: Utility Rebate Program • Eligible Technologies: Photovoltaics • Applicable Sectors: Commercial, Industrial, Residential, Nonprofit, Schools, Local Government, State Government • Rebate: \$3/W_{ptc} for residents, \$3/W_{ptc} for businesses • Effective Date: July 2001 • Website: www.burbankwaterandpower.com/rebate.htm
City of Palo Alto Utilities – PV Partners • Incentive Type: Utility Rebate Program • Eligible Technologies: Photovoltaics • Applicable Sectors: Commercial, Residential, Nonprofit, Schools, Local Government • Rebate: Residential customers: \$4/W_{ptc} up to \$12,000 maximum; Commercial Customers: \$2/W_{ptc} up to \$50,000 maximum • Distributions: 53 systems, 189 kW_{ptc} • Date Enacted: 1999 • Expiration Date: Up for annual renewal each June • Website: www.cpau.com/programs/pv-partners/pvindex.html
Los Angeles Department of Water & Power – Solar Incentive Program • Incentive Type: Utility Rebate Program • Eligible Technologies: Photovoltaics • Applicable Sectors: Commercial, Residential • Rebate: Locally (in-city) manufactured solar products: \$6.00/W_{ptc}; \$60,000 max (residential); \$2 million max (commercial); All other solar products: \$4.50/W_{ptc}; \$50,000 max (residential); \$1 million max. (commercial) • Distributions: 2.6 MW_{ptc} subscribed by end of 2002; another 2 MW_{ptc} expected in 2003 • Date Enacted: September 1, 2000 • Expiration Date: December 31, 2010 • Website: www.greenla.com/solar/incentives/index.htm
Redding Electric – Vantage Renewable Energy Rebate Program • Incentive Type: Utility Rebate Program • Eligible Technologies: Solar Water Heat, Photovoltaics, Photovoltaic Attic Fan • Applicable Sectors: Commercial, Residential • Rebate: PV: 50% of project cost up to \$15,000; Solar Thermal: 50% of project cost up to \$1,000 for the first panel, up to \$500 for the second panel and up to \$250 for the third panel; Solar PV Attic Fans: 50% of project cost up to \$250/unit • Terms: Solar water heaters must replace electric water heating systems • Date Enacted: January 1, 2002 • Effective Date: March 1, 2002

• Website: www.ci.redding.ca.us/ electric/energysvc/renewables.html
Roseville Electric – Solar PV Buy-down • Incentive Type: Utility Rebate Program • Eligible Technologies: Photovoltaics • Applicable Sectors: Commercial, Residential • Rebate: $5/$W_{ptc}$ for systems up to 5 kW_{ptc}, the maximum rebate is $25,000 • Website: www.rosevilleelectric.org/programsRebates/renewablePrograms/solarPvBuydown.html

Incentives in Other States (SEPA 2003)

Many states in the nation have similar incentive programs. The New Jersey Clean Energy Program (NJCEP) offers rebates of up to $5.50/$W_{ptc}$ for systems less than 10 kW_{ptc} — rebates decrease as system size increases. The NJCEP is modeled after the Energy Commission's program in order to stimulate the market through a large quantity of small purchases. Many interviewed for this report felt that this approach was the best way to strengthen local PV infrastructure and develop the PV industry. Other programs have relied on aggregate purchases of PV from one vendor, which may result in lower system prices but it builds fewer businesses.

Incentives are most often based on performance or system size. Incentives take many forms including tax credits, direct rebates, and financing options. Below are several options for rebates:

- A fixed rebate of a given dollar amount per Watt (e.g., $5/$W_{dc}$).
- A rebate to the manufacturer, enabling it to sell modules at a lower price.
- A percentage-based rebate with a dollar per Watt cap (e.g., 50% rebate, up to $4.50/$W_{ptc}$).
- A percentage-based rebate with a fixed dollar cap (e.g., 15% of all system costs, up to $2,000). Many state tax credits are structured this way.
- A production-based rebate, based on kilowatt-hours produced over a period of time (e.g., $1/kWh for the first year's system production), rewarding installation of efficient and well-designed systems. (Several inverters have built-in displays of power produced that may provide a basis for an incentive).[24]

3.2.3 Utility PV and Grid-Tied Markets

The grid-connected market includes applications for utilities, communities, homes, and commercial buildings. This market is the focus of most utilities and much of the PV industry.

Despite costing more than other options, PV is an important component of a utility's renewable energy portfolio, because it is the most visible renewable energy technology and can be located in populated areas. By deploying PV in high visibility areas, utilities can create a greener image

24. Even if the margin of error for an inverter display were to be 10%, a production-based incentive using this figure would still be substantially more precise in channeling clean energy incentive dollars to clean energy generation than any capacity-based incentive could be. Power produced is only *approximated* by rated capacity, since weather conditions, system design, and orientation can result in major differences in actual power output.

while educating the public about renewable energy. This is a difficult value to quantify, but it does provide very valuable public relations benefits. PV is the only renewable energy technology that can be installed almost anywhere in a utility's distribution system.

Community Involvement and Schools[25]

Many commercialization programs have targeted public buildings and schools for PV installations because PV provides more than just electricity; it also serves to educate the public about solar energy. Once people become familiar with solar through their community, they are more likely to support future solar projects or choose to purchase their own PV system. This market may be served by utilities or the PV industry, and holds great potential for growth.

Figure 8. Wisconsin Public Service Company's SolarWise for Schools Programs participate in the annual Solar Olympics, shown here, as part of their educational curriculum.

Photo Credit: SolarWise

PV systems on schools are an ideal way to gain community interest and educate local consumers about solar energy. Schools often have large, flat, shade-free rooftops that are well-suited for PV. Additionally, schools are an ideal location for PV because the peak output of PV coincides with their large daytime load. Even in the summer, when schools are not in session, electricity from the PV will feed into the grid, offsetting peak demand elsewhere in the local area.

Most schools with PV systems have developed educational programs related to environmental and energy awareness based on data collected from the PV system. For most schools, the educational value is greater than that of the energy produced by the PV system. As students become excited about PV, their interest is transferred to their parents who, in turn, are more likely to support other PV projects. Systems installed on public buildings such as courthouses and fire stations also provide many of the same public relations and educational benefits as schools and also help to offset peak electricity costs. Green power programs can be used to further offset the cost of new PV systems and maintenance on existing systems. Many municipal utilities have supported this type of program. Depending on the available funds, there is a large market potential.

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25. From the *Solar Power Solutions Showcase Projects Final Report*, http://www.resourcesaver.com/file/toolmanager/CustomO63F36850.pdf

Large-Scale Applications

Large PV systems (usually defined as 100 kW_{ptc} and larger) are ideally suited for utility green pricing programs and bulk power sales and for significantly reducing customer loads (as shown in Figure 9). Large-scale PV systems require utility-scale interconnections to the power grid and allow for electrical optimization of design and production of three-phase power commonly used for power delivery. Consequently, large PV systems are generally sited on commercial and industrial buildings, on utility property, and can be rooftop- or ground-mounted (as shown in Figure 10).

Figure 9. Tucson (Arizona) Electric Power Company is realizing the value of PV with this utility-scale installation, which now totals more than 4 MW_{ptc}.

Photo Credit: AstroPower

Finally, the large size of such systems makes it possible to minimize design, permitting, installation, and balance-of-system costs on a per-kilowatt basis.

Utilities and corporations are recognizing the value of large-scale PV, and many high-profile corporations have recently installed large PV systems at their facilities. Johnson and Johnson installed hundreds of kilowatts of PV at several of its facilities throughout the country. Toyota has also recently built a facility that demonstrates many green building technologies as well as a large PV system. By purchasing large PV systems to power significant portions of their facility loads, these businesses are stabilizing electricity expenses well into the future. These businesses do benefit from the public relations aspects; however, the primary driver is economics.

Figure 10. Domaine Carneros Winery in Napa Valley, California, installed a 200-kW$_{ptc}$ PowerLight PV system, shown here, that supplies 40% of the facility's electricity needs.

Photo Credit: AstroPower

Residential PV[26]

The residential market for PV has huge potential with many products available that are specifically designed for residential installations. Deployment efforts have been focused on both retrofitting existing homes and working with builders and developers to install PV in the new home production market. While a promising market, residential systems pose some unique challenges, particularly in California.

Residential system costs tend to be higher per kilowatt than commercial system costs because much of the basic design and permitting is required independent of system size. The variation between roof design, penetrations, chimneys, and shading causes residential systems to require additional customization. Therefore, to minimize cost, careful planning and system selection are necessary and packaged systems should be used whenever possible.

26. *TEAM-UP Residential PV Systems Cost Report,* http://www.resourcesaver.com/file/toolmanager/O63F22750.pdf

Figure 11. PV Pioneer II home in Sacramento, California, an example of a retrofit PV system.

Photo Credit: AstroPower

Most PV systems are currently installed on existing grid-connected homes where the system designer must work with the existing structure, as shown in Figure 11. The design of a PV system needs to optimize the performance based on the roof orientation, surrounding obstructions, and aesthetics, all of which can increase the cost of the PV system. Some homes are not feasible locations for PV because they have too much shading; the roof type cannot support a PV system; or they have poor orientation or slope. Therefore, a careful assessment of the home should be done before a PV project proceeds.

Installing PV on new homes offers some benefits, but also has barriers. By partnering with large-scale home builders, the PV industry can sell identical systems in large quantities, reducing cost through mass production. Homes can be designed to maximize the benefits of PV through energy efficiency measures and roof orientation. The cost of the PV system can also be rolled into the mortgage, making financing simple and receiving relatively low interest rates. In such situations, the utility bill reductions can equal or exceed the amount that the PV system and efficiency measures added to the loan payment.

Homebuilders have shown interest in working with the PV industry and utilities in the hopes of offering PV in new home developments. Their main concerns are maintaining schedules and profitability. As noted during interviews, PV stakeholders with experience working with home builders have found that the addition of a PV system to a new home must go smoothly to continue the partnership because any delays are likely to discontinue the business relationship.

3.2.4 Off-Grid Markets

Most of the focus of this report and this project has been on grid-connected applications. Many off-grid applications for PV are viable without subsidy and are diverse. Utilities may serve few off-grid customers, with the exception of electric co-ops, although urban applications for off-grid PV are growing and are a unique opportunity for utilities to embrace the technology.

Off-grid markets have a thriving business community to support them, and the utility role is not necessarily as competitor but as facilitator of the expansion of these markets and applications. This provides value to the utility because it reduces uneconomic service to certain loads and demonstrates to the public a commitment to renewable energy. Stakeholders interviewed expressed strong concern that utilities not become competitors with the existing off-grid PV industry.

Off-grid PV applications that hold potential for utility use include:

- Street and parking lot lighting.
- Illumination of signs, billboards, and crosswalks.
- Irrigation pumps and controls.
- Landscape and architectural lighting.
- Security systems for the homes and businesses.
- Emergency power supply for businesses.
- Cathodic protection of utility assets.

Using PV to replace remote line extensions has benefits for both the utility and the customer. Grid-independent PV systems used in place of line extensions can be cost-effective and can be more reliable than long, lightly loaded feeder lines. An example using PV for line replacements was part of the TEAM-UP program. Through TEAM-UP, The Nature Conservancy worked with local utilities to install grid-independent PV systems, with battery or generator back-up, to allow the removal of very long and underutilized utility distribution lines serving remote, pristine areas.

3.2.5 Critical Success Factors

The SEPA Solar Power Solutions project developed a list of Critical Success Factors for community programs, which are actions necessary to expand PV markets. The results of this SEPA study for SMUD verified that these factors are important. These critical factors define a holistic approach to PV commercialization and help ensure that customer demand, infrastructure, and the technologies are developed simultaneously. PV deployment efforts should incorporate elements of each of the Critical Success Factors to have the maximum market impact.

The Critical Success Factors are:[27]

- **Technology Development** — Customer needs must be understood and the elements of the PV technology must be fully developed and ready to cost-effectively meet those needs. Communicate that PV is currently ready to provide grid-connected distributed generation across the nation. Further research and development will reduce costs,

27. From *Solar Power Solutions Showcase Projects Final Report.*

- **State and Federal Policies Aligned** — The government, at all levels, must provide the appropriate mix of incentives, actions to reduce barriers (permitting and approvals, for example), and procurement to allow PV technology to address target markets. Many states have developed policies for PV, while others are not as far along and would benefit from the lessons of others. SEPA recommends federal policies, among other goals, serve to support state actions.
- **Electricity Provider (Utility) Acceptance** — The local utility cooperates and helps the end user to insert PV as a seamless addition into the existing power grid. Utility acceptance of PV is a critical factor for market development, as even the highest incentives and most enthusiastic supporters can be stalled by prohibitively difficult utility interconnection requirements.
- **Downstream Infrastructure** — Product distribution and service networks are sufficiently developed to support PV within the market area and segment. Any initiative to deploy PV requires locally available PV systems and qualified personnel to install and service them.
- **Informing the Market** — The end users and stakeholders within each market segment need to be properly informed of the value proposition of PV. In some cases, PV is cost-effective simply on its energy value. In other cases, the total value proposition is more complicated, but still makes PV the highest-value choice. Informing the market of the total value proposition will create sustained and growing demand for PV.
- **Financing Options** — Flexible, tailored, and widely available finance vehicles open the market to more customers. Because of its high up-front cost but very low operation and maintenance costs, PV benefits greatly from the availability of low-cost, low-hassle financing options such as mortgage lending or asset-based leasing programs.

3.3 SMUD's PV Activities

3.3.1 The Past and Present SMUD PV Program

SMUD is the fifth largest public utility in the nation and serves a 900-square-mile area in and near Sacramento County, California. SMUD's mission as a customer-owned utility is to meet the electric and energy service needs of its customers in a safe, reliable, economical, and environmentally responsible manner. SMUD is transmission constrained with limited ability to import power to its service territory, and is also located in a region with air pollution problems that limit power generation options.

SMUD has the unusual characteristic of being managed by a Board of Directors elected by SMUD customers who are responsible only for the utility. The Board of Directors determines policy for SMUD and appoints the General Manager, who is responsible for the utility's operations. Most other municipal utilities are managed by a City Council or Board that is

responsible for municipal functions that go well beyond the electric utility to include parks, streets, and schools.

3.3.2 A Brief History of the SMUD PV Program

SMUD has had an ongoing PV program since the early 1980s, positioning itself as the leader in utility PV. To date, SMUD has installed more than 10 MW_{ptc} of PV, more than any other utility in the world. The evolution of the SMUD PV program has taken several steps. SMUD's first PV activities in the early 1980s were large and aggressive. Utilities at the time were looking at PV to be a bulk, "utility megawatt scale" power resource and SMUD's PV program was intended to be a significant market stimulating effort. SMUD installed a 1 MW PV plant next to the (then operating) Rancho Seco nuclear power plant (Figure 12), a juxtaposition of images that defined it during this period.

SMUD had plans to install more megawatt-size PV plants in a stair-step fashion in the surrounding buffer land at Rancho Seco. This first plant, PV1, went online in August 1984 with a dedication ceremony and predictions that PV prices were to decline steeply. SMUD planned more PV installations if the decline in prices met expectations.

As the prices of turnkey, completely designed, and installed PV systems continued to decline on the SMUD expectation path, a second 1 MW PV plant, PV2, was installed at Rancho Seco in March 1986.

Figure 12. PV 1, a 1 MW PV system located at the Rancho Seco nuclear power plant

Photo Credit: AstroPower

SMUD stopped plans for a 5 MW PV plant, PV3, when the equipment bids were higher than expected for a plant at that time and of that size. The module costs for PV2 were at $4.80/W and were expected to decline considerably for the next system. The PV module bids for PV3 were at $4.29/W and the program had a target of $4/W, so SMUD decided to halt these PV efforts. Pacific Gas and Electric and its PVUSA efforts took the utility-scale PV demonstration lead from 1987 to 1993.

In the early 1990s, PV was a focus of SMUD management when the PV Pioneer program was launched as an outcome of PVUSA, U.S. DOE programs, and other efforts that identified the increased value of PV as a smaller distributed generation resource rather than as a large multi-megawatt PV power plant. Although SMUD had decided to continue to install medium-size PV systems (approximately 100 to 200 kW_{ac}) at the Hedge Substation and larger PV systems at Rancho Seco for grid support and PV system/component validation, SMUD's prime focus became smaller, customer-sited PV systems. (There are now six systems installed at Rancho Seco totaling approximately 5 MW.)

SMUD launched the PV Pioneer I Program in 1993, partnering with customers who chose to pay an extra monthly "green fee" to host SMUD-owned PV systems on their roofs. The program's goals were to develop the experience needed to successfully integrate PV as distributed generation into the utility system, develop long-term market and business strategies, and accelerate the cost-reductions necessary for PV to be cost-competitive in residential applications.

SMUD's residential PV Pioneer I customers volunteered to participate in this effort through a form of green pricing and provided the roof area for the SMUD-owned PV power plants. The PV Pioneer I homeowners pay a $4 per month premium on their utility bills to participate. SMUD gained experience in the installation, operation, maintenance, pricing strategies, and other aspects of residential PV systems and obtained low-cost sites for its PV systems. This joint effort also helped accelerate the commercialization of PV as part of a process SMUD called "sustained, orderly development." This expression was intended to suggest that regular, increasing, predictable orders of PV systems would lead to steady, yet growing manufacturing capacity and lower prices, more than episodic purchases would.

PV Pioneer I systems, each about 3 to 4 kW, are connected to the utility side of the residential service meter and enter the utility grid through a separate utility kilowatt-hour meter mounted next to the home's electric kilowatt-hour meter. The impact is that the customer does not directly benefit from the electricity generated by the PV system; the PV is viewed as a utility power plant and directly feeds the utility grid. Approximately 100 PV Pioneer I systems were installed each year from 1994 to 1999. There are currently more than 600 PV Pioneer I installations.

In September 1996, California Assembly Bill 1890 directed a comprehensive restructuring of the electric industry in California. AB 1890 established the Energy Commission's Emerging Renewable Program (ERP) that is open to the ratepayers of the three biggest IOUs in California: Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). Beginning in 1998, the Energy Commission's ERP began offering rebates for grid-connected PV systems. In 2001, the California Public Utilities Commission (CPUC) began the Self-Gen Program. The Self-Gen Program also offers rebates, but the program is administered by the utilities (PG&E, SCE, SDG&E, and Southern California Gas Company) directly. SMUD, the Los Angeles Department of Water and Power (LADWP), and other municipal utilities offer their own incentive programs.

AB 1890 also helped establish the use of SMUD public goods funds for an incentive, the source of the funding for the SMUD PV Pioneer and PV program activities. As part of the response to restructuring, SMUD expanded its PV program under the AB1890 mandated Public Goods Fund program.

In 1998, to meet the demand for equipment for PV Pioneer I, SMUD implemented a competitive procurement that resulted in a contract with Energy Photovoltaics, Inc. (EPV) to supply 10 MW_{stc} of PV modules over a five-year period and to establish a PV module manufacturing plant in Sacramento. The long-term PV purchase contract anticipated favorable pricing resulting from the high-volume, multi-year agreement, and the manufacturing facility was to help spur local development as required by the SMUD Board. The development package included a contract with Trace Engineering to supply inverters and locate an inverter assembly facility in Sacramento, as well as a contract for installation services from Utility Power Group. An additional contract with Atlantis Energy provided SunSlate BIPV roofing systems to SMUD.

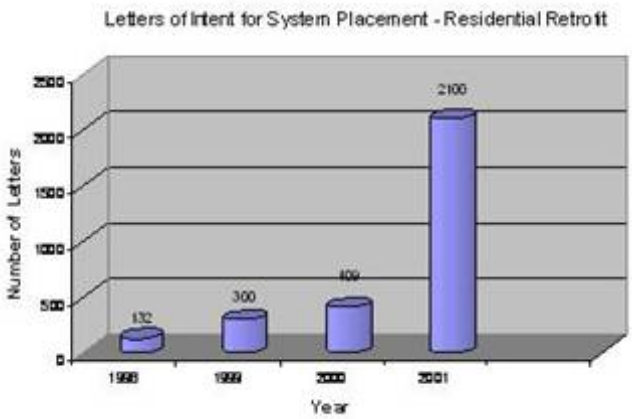

Figure 13. Letters of intent for PV Pioneer programs from SMUD customers
Source: Sustainable Conservation

In 1999, the PV Pioneer II program started offering reduced price PV system sales directly to customers. PV Pioneer II, which continues today, was a logical progression from PV Pioneer I. Unlike the PV Pioneer I Program, the PV Pioneer II systems are owned by the customers. SMUD buys down the cost of the PV systems to about $2.50 to $3.00/W, and the resulting effective cost of PV electricity, when financed in a home mortgage, is competitive in the California residential electric market. The customer also receives net metering. Currently, there are more than 200 PV Pioneer II participants (see Figure 13). It should be noted that the PV Pioneer II Program is presently being transitioned to a market-driven program, where many of the functions

previously provided by SMUD will be turned over to an emerging base of qualified contractors. The market-driven program will be similar to SMUD's energy-efficiency programs. Private-sector PV companies will take responsibility for portions of the program now handled by SMUD and SMUD's role will eventually be limited to providing rebates, informing and educating consumers, providing interconnection, and performing net metering.

The PV R&D staff initiated a contractor training program, covering both installation and system design, to establish a base of certified contractors that can offer turnkey high-quality systems at a reasonable cost. The transition to a market-based program is scheduled to occur in 2005. Based on the success of the Pioneer II program and budget constraints, the expansion of the PV Pioneer I program was discontinued in 2001.

The California energy crisis of late 2000 and early 2001 created a large customer demand for residential PV systems. Figure 13 shows the pronounced increase in PV system requests that SMUD received in 2001.

As part of the SMUD Sustained, Orderly Development, and Commercialization (SODC) program, another 30 commercial rooftop and parking lot systems, ranging from 4 kW_{ptc} to 540 kW_{ptc}, provide more than 1.5 MW_{ptc} of solar capacity on SMUD's grid. A few of these commercial building systems' designs simply combined multiple residential systems, rather than being customized for the site. Several BIPV systems have been installed at SMUD facilities and numerous new homes in the SMUD region have PV roofs that use SunSlate BIPV shingles.

In 1999, SMUD installed its first school PV system under the Neighborhood PV Pioneer program. The Kit Carson Middle School hosts a 28 kW BIPV system that uses SunSlate PV roofing shingles. SMUD is also providing curriculum support to schools with PV systems and provides PV workshops for educators throughout the District.

Figure 14. East End Solarport in Sacramento.
Source: Sustainable Conservation

Figure 15. 540 kW_{ptc} Solarport at the Cal Expo grounds in Sacramento, California.

Source: Sustainable Conservation

SMUD was one of the first to utilize the unused space above parking lots as sites for PV systems — Solarports — that also offer the benefit of shade for the vehicles below. Several Solarports have been installed by SMUD over local parking lots and more are planned. A few of these systems are also utilized as electric vehicle charging stations. The world's largest PV parking lot system, 540 kW_{ptc}, was completed in mid-2000, with partial funding by SEPA's TEAM-UP program, at Cal Expo, the site of the California State Fair in Sacramento.

In 2002, SMUD determined that the partnership with EPV was not successful and CalSolar support was halted.

From 1993 to 2002, the SMUD PV Program completed more than 1,000 distributed PV installations with a total capacity exceeding 10 MW_{ptc}. SMUD's program led the way for other utilities to adopt PV and helped the PV market to grow.

3.3.3 Current SMUD PV Program

SMUD continues to be a PV leader. SMUD's justifications for the continued efforts are:

- PV is what its customers want.
- Customers believe that distributed and renewable generation sources are the future, and PV is both.
- PV can shave peak loads; provide grid support, sustainable development, and local economic development; and is a hedge against fossil fuel price shocks.
- Public relations benefits of PV alone justify the cost.
- PV could be a future profit-making business venture.

The current SMUD PV program contains the following components:

- ReGen, a research, development, and demonstration program, largely funded by the PIER program.

- Residential PV (PV Pioneer I and II).
- Neighborhood PV (Non-Profits).
- Commercial (large & small).
- Utility Scale (ground mounted large installations for bulk power).

The SMUD PV program from 1993 to 2002 was conducted by a concentrated, entrepreneurial group of SMUD employees under the management of the Energy Supply Business Unit (ESBU). In 2002, the PV program was divided between two of SMUD's business units. The customer contact efforts of the PV Pioneer and other functions of the PV program were determined to be better suited to SMUD's Customer Service Business Unit (CSBU), while other functions remained at the ESBU. CSBU has the experience of regular and focused customer relations for energy efficiency, air conditioning, and weatherization programs, and management felt that PV applications had grown into a mature business that could be best managed in this department. The ReGen program, new residential construction, partnerships, and utility-scale PV grid-support remain with the ESBU.

3.3.4 The ReGen Program

ReGen is a PIER project funded by the Energy Commission that provides $13.65 million in Energy Commission funds to 19 projects.

Table 4. The ReGen Projects Through PIER

The ReGen Projects
1.1 Technology Assessment for Advanced Biomass Power Generation, UC Davis
1.2 Photovoltaic Markets and Technologies, Solar Electric Power Association
1.3 Utility System Capacity and Customer Demand Value of PV, Clean Power Research and NREL
1.4 Performance Indexing of PV Systems, Southwest Technology Development Institute
1.5 Assessment of Worst-Case Weather Conditions, RLW Analytics
2.1 Accelerated Anaerobic Composting for Energy Generation, Yolo County
3.1 Laminate & Batten PV Roofing System, Uni-Solar
3.2 BIPV Mounting Approaches for New Construction, RWE Schott Solar
3.3 Mainstreaming PV for Residential Roofs, PowerLight Corporation
3.4 Flat Roof Mounting Approaches, RWE Schott Solar
3.5 Optimization of Residential PV Systems, AstroPower
3.6 Remote Dispatch & PV Irrigation, WorldWater Corporation
3.7 PV & Evaporative Cooling, Davis Energy Group
3.8 Solar Dish Concentrating with Stirling Engine, SAIC
4.1 Non-Vacuum Thin Film CIGS Modules, Unisun
4.2 Maximum Power Point Tracker Inverter Development, SMA America
4.3 Hybrid PV/Lighting System, Oak Ridge National Laboratory
4.4 Slat Array Concentrator, SVV Technology Innovations
4.5 Drivetrain for High Torque Wind Turbine Applications, Clipper Windpower

Many of the individual project teams, as well as SMUD, provide cost share for the program to complement the funds provided by the Energy Commission. The majority of the ReGen projects deal with developing new renewable products for use in the SMUD territory and other California markets.

The ReGen program goals and objectives are to:

- Develop technologies to open broad renewable energy markets.
- Develop resources that will allow SMUD to increase its portfolio of renewable generating assets.
- Help SMUD reduce its summer peak-period demand for electricity.

- Make Sacramento a center for the development of new renewables.
- Reduce the cost of PV installations.
- Begin to develop new biomass generating possibilities.
- Develop and test a wind technology potentially suitable for SMUD's Rio Vista wind farm.
- Test and develop concentrating solar power generating systems.
- Develop results that will have an impact outside of SMUD territories, throughout California.

To fully understand the ReGen program, one needs to review the wide variety of projects in the program, listed in Table 4. The ReGen program's website, http://www.smud.org/community-environment/renewable/index.html, provides additional information about the projects.

Almost all of the projects were initiated in late 2001 or early 2002 and all projects will be complete in 2004 with final reporting in 2005. A new set of ReGen projects will start in 2005.

3.3.5 Customer PV Program

SMUD's Customer PV Program includes new-construction residential, retrofit residential, and commercial-customer PV applications. The Customer PV program has the following goals:

- Meet SMUD's strategic resource goals that call for at least 10 MW_{ptc} of new PV capacity by 2006 through a variety of retrofit, new residential, and commercial PV initiatives (this goal may change as SMUD's strategies evolve, including its RPS response).
- Contribute to the continuation of SMUD's national leadership in renewables.
- Foster the development of an unsubsidized marketplace by developing a delivery infrastructure and refining marketing knowledge.

There are two elements of the Customer PV Program:

- PV Pioneer Residential PV (retrofit for existing homes and also new home construction).
- Commercial PV (covering both large and small commercial installations).

The residential housing market in the Sacramento area continues to show high growth rates. More than 15,000 new homes have been constructed in the region each year for the last two years. That load growth is an incentive for SMUD's residential PV program.

3.3.6 Residential PV

PV Pioneer II, Residential Retrofit

PV Pioneer II aims to accelerate the market penetration of residential retrofit PV by offering an installed system at approximately half the market price, with the quality of performance and installation backed by SMUD. To this end, SMUD serves as a full-service PV retailer responsible for product acquisition, marketing and market research, installation, and customer service.

In 2003, the program began a transition to a contractor-provided program. In this model, similar to SMUD's energy-efficiency program, private PV companies take the responsibility for portions of the process, and SMUD's role is increasingly limited to providing customer rebates, informing and educating consumers, and providing interconnection and net metering. The PV R&D staff initiated a contractor-training program, including both installation and system design skills, in order to establish a base of certified contractors that can offer turnkey systems to customers at the cost and quality levels that meet SMUD's standards. The timing of this transition and the functions that will be the responsibility of the contractors have not yet been determined.

Marketing and advertising efforts for PV Pioneer II consist of direct mail, trade shows, and web-based information. Customer representatives initially screen contacts and solar specialists follow up on promising leads and carry out the remainder of the sales process, including structural analysis, system design, and execution of the contract. Two installers under contract to SMUD do the actual installations.

The residential retrofit PV market in Sacramento is an important market segment, one in which existing SMUD customers desire SMUD support. However, this residential retrofit market:

- Will always be the high-cost market segment.
- Is composed of individual, semi-custom installations.
- Has high transactional cost.
- Is serviced by poor financing options unless it is part of a refinance.

PV Pioneer II, Residential New Construction (Solar Advantage Home Program)

The Solar Advantage Home Program's goal was to develop practical models for zero-peak homes and to demonstrate their marketability. While SMUD's new home construction PV applications have been put on hold, this section will still address the program's efforts and the strategy that was in place in early 2003.[28]

There are signs that both improved energy codes and consumer interest in high-performance homes will move production homes ever closer to eliminating the peak demand. SMUD will continue to improve its Solar Advantage Home program in order to exert maximum leverage in this direction, with the goals of:

- Researching and demonstrating new roof-integrated PV products.
- Researching the impact of PV on the SMUD peak load and distribution system.

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28. SMUD suspended the Solar Advantage Home program in January 2003. As a result, it no longer has an active new construction program open to all builders. Currently, SMUD has a Zero-Energy Home program in cooperation with U.S. DOE/NREL. There are two builders that are participating in this program: Morrison Homes and Premier Homes. Morrison Homes has one ZEH community in which it will build up to 20 ZEHs in a 120-unit subdivision and offer them as optional upgrades and/or as spec houses. Premier Homes will construct a 94-unit, all-ZEH subdivision in 2004.

- Integrating PV into the SMUD residential new construction program.
- Removing most on-peak load while retaining off-peak load.

The SMUD Solar Advantage Home program was initiated in early 2000 through a series of meetings and workshops with local builders sponsored by the Building Industries Association. Local builders expressed an overwhelming preference for BIPV over building-applied PV (BAPV) systems, and specified that any product must be:

- Priced to keep the home cost-competitive.
- Easily integrated into normal construction and permitting procedures.
- Compatible with concrete tile roofs.
- Aesthetically acceptable.

Builders and homebuyers have shown increased interest in the Solar Advantage Home program because it produces homes that allow occupants to reduce their energy bills. A few national builders, who are also among the prominent builders in the Sacramento area, have shown consistent interest in the zero-energy home as a concept capable of attracting buyers. Buyers are able to finance the system through a low-interest, tax-deductible home mortgage.

Four barriers to increased sales of PV-equipped homes are:

- The high price and unreliable supply of PV products acceptable to production builders.
- Lack of a sales strategy that offers PV as an option competing with more traditional options (enhanced kitchens, lighting upgrades, etc.).
- Lack of infrastructure to install and support PV systems on new homes.
- The relatively low price of grid-supplied electricity.

Installing a PV system during construction, rather than in a retrofit, reduces costs. Builders installed the Atlantis SunSlate System at \$1 to \$1.40/W_{ptc} versus \$2/W_{ptc} typical of retrofit installations.

Eight builders have participated in the SMUD Solar Advantage Home program, including Beazer Homes, Morrison Homes, U.S. Home Corp., Forecast Homes, Christopherson Homes, R.W. Hertel & Sons, Prodigy Homes, and Tim Lewis Communities. Although the program has been suspended, several builders remain interested if the right product can be obtained. In 2002, local builders sold 43 PV-equipped new homes, up from 24 in 2001. In the life of the program, builders completed 124 Solar Advantage Homes.

3.3.7 Commercial-Sector PV

SMUD's Commercial PV program is focused on increasing the number of grid-connected, customer-owned PV systems on commercial buildings. To do this, SMUD offers incentives comparable to their residential programs.

The Commercial PV program goals are to:

- Perform extensive market research, relying on customer visits and focus groups consisting of a representative sample of large commercial customers, to derive realistic, empirical estimates of the potential market and to determine whether SMUD's program can meet customer needs. SMUD had determined in prior years that it needed to better characterize the market—including customer motivation, purchase drivers, and product preferences—to make this program element successful.
- Offer a supplemental rebate to be added to the Self-Gen rebate, recruit a master list of high-quality contractors, and support their marketing efforts by helping identify customers whose usage patterns make PV a promising investment.

3.3.8 PV Partnerships

The purpose of PV Partners is to help public organizations outside the SMUD territory acquire PV systems by offering them high-quality PV modules at reduced prices made possible through SMUD's volume purchasing. SMUD facilitates PV purchases by public institutions that are new to PV. SMUD serves as a reseller, allowing the client agencies to significantly reduce the time and resources they would otherwise need for research, RFP drafting, negotiations with bidders, and contracting.

The program has the following objectives:

- Allow SMUD to place larger orders and thereby decrease module prices.
- Assess the opportunity for developing a revenue-earning PV consulting and project management business for SMUD.
- Establish a model for cooperative buying as a standard procedure among public agencies.

By fostering collaborative relationships with a group of organizations committed to developing solar electricity, this program supports SMUD's larger strategic objective of maintaining national leadership in the reduction of costs for renewable energy. SMUD should be able to mark-up the price to cover administrative costs and still offer a competitive price to its partners.

SMUD may not have to purchase and warehouse the modules prior to making sales if it can arrange with manufacturers to reserve a given amount of capacity and to deliver product as needed. The key is getting the partnerships in place and the purchases synchronized.

SMUD will explore the feasibility of an expanded role throughout California, possibly to include technical and economic consulting and project management.

There are some concerns and issues that need to be addressed in SMUD's PV Partnership program:

- Lack of adequate market information and the response time to satisfy demand.

- Added administrative costs with a mark-up to institutional buyers, added cost of its purchased products, or both.
- Potential of an adverse reaction from the PV industry to SMUD assuming an expanded role as a product vendor using public subsidies to undersell the private sector.
- Potential product and professional liability on services provided.

This leadership/partnering role is not for all utilities. It is possible only if the utility is already a sizeable factor in the market and is supported by management and its governing board in its exercise of this market-leading strategy.

SMUD has sold nearly 540 kW of PV to the following PV partners:

- Bishop Fairground (63 kW_{ptc} / $284 K)
- Lakeport Fairground (29 kW_{ptc} / $103 K)
- Ridgecrest Fairground (123 kW_{ptc} / $445 K)
- Chico Fairground (93 kW_{ptc} / $326 K)
- City of Davis (90 kW_{ptc})
- Riverside Public Utilities (139 kW)

SMUD has a history of partnering with other utilities in California and elsewhere. The PV Partnership program is a natural extension of these efforts.

3.3.9 Successes of the SMUD PV Program

SMUD has been a leader among utilities, using PV to provide grid support to its distribution network. SMUD has successfully leveraged available state and federal funds to expand its program at every opportunity. S. David Freeman and Don Osborn have been identified as visionaries for the SMUD PV efforts, and both played critical roles in the initial approval of the PV program at SMUD. The SMUD Board of Directors has provided support for the utility's initial efforts because of strong consumer interest in clean and renewable energy. The Board maintained SMUD PV strength and support, ensuring the continuation of this effort through some serious energy capacity problems in California.

SMUD's program has been successful because the utility has:

- Created a direct relationship with its customers, and the PV program has enhanced SMUD's positive image.
- Established a vertical integration of the PV Pioneer process with sales, supply, installation, and operation.
- Offered potential PV Pioneer customers a comprehensive site assessment to create customer support.

- Utilized standard practices and simple, low-cost, flexible mounting hardware and design layouts to minimize labor costs.
- Utilized multi-year volume purchases to procure low-cost modules and inverters.
- Used factory panelized modules and pre-packaged kits for many of the installations, enabling residential system installation in a single day.
- Trained a network of traditional contractors in the Sacramento region.
- Developed strong relationships with local building agencies that helped streamline the permitting and inspection processes.

3.3.10 Observations on the SMUD PV Program

To collect data for this report and other efforts in this project, SEPA conducted a series of interviews with representatives from utilities, the PV industry, and other stakeholders. These interviews provided a unique perspective on SMUD's PV activities, in addition to broader observations about the California PV market. There were 18 representatives from the utility industry, 19 PV industry representatives, and 4 other stakeholders interviewed. This section reflects their views on the SMUD program.

- SMUD has been a leader in developing utility involvement in PV and higher performance and operating standards.
- SMUD has been a strong leader in the development of simple PV system and utility grid interconnection requirements. The utility identified the need early to establish a simple set of interconnection requirements for customer-sited PV systems of 100 kW_{ptc} or less.
- SMUD staff was involved, and their experiences played an important part, in the establishment of the UL 1741 and IEEE 929 standards development.
- SMUD efforts and experiences were key in the establishment of the California state net metering law. Under the California AB1755 Net Metering Legislation, every electric service provider is to develop a standard contract or tariff for net metering and to make this available to eligible customer generators on a first-come, first-served basis. Each utility is required to provide net-metering at least to the point where capacity of customer generation equals 1/10 of 1% of the electric service provider's peak customer demand. For SMUD, this lower limit represents about 2.6 $MW_{ptc,}$ or the equivalent of 1,300 PV Pioneer II type residential systems.
- SMUD led the way for many utilities and pushed for the requirement that interconnected PV systems be installed by a licensed electrical contractor according to the National Electrical Code.

The lessons learned from the implementation of SMUD's program are not well documented and there has been only minimal information disseminated. Many of the staff during the intense RFP, procurement, and implementation days of the Pioneer I and II programs are no longer employees of SMUD. Limited information was released to the PV community from SMUD, and

items such as performance, cost, and actual cost reductions are not available. The publications and presentations that were available included few insights and only the very positive lessons. Real and verified cost breakdowns of the PV modules, balance-of-system components, installation, and operations and maintenance costs were not clearly documented.

The costs reported to those outside of SMUD did not include SMUD program or overhead costs, giving others unrealistically low expectations for the cost of purchasing and installing PV systems. The PV community outside of SMUD had concerns that inaccurate, or at least misleading, cost information made it difficult to sell PV in California during the period prior to the energy crisis in 2000 and 2001. Although it remains difficult to quantify the true costs of PV under the SMUD program, there appears to be a general 10 to 20% difference between actual PV system costs incurred by others and those reported by SMUD.

SMUD's partnership with EPV (CalSolar) had a negative impact on the California market for the Sacramento region. Many people interviewed said they were skeptical of the partnership at the first announcement and, from the onset, there was a low probability that the EPV product, price, efficiency, and production rates would be reached within the proposed plan. The inability of the CalSolar plant to meet production and cost goals was apparent to those outside SMUD years ahead of the acknowledgement of the SMUD's shortfall.

The exclusive agreement with EPV left a supply void in the Sacramento region. Furthermore, SMUD's use of subcontracted installers may have had an adverse impact on the development of the local PV infrastructure. Sacramento continues to lack a strong PV infrastructure due to the prolonged turnover of outside installation contractors. Fortunately, the availability of the CPUC buy-down funds in Sacramento (through Sacramento area PG&E natural gas customers) has allowed other suppliers to sell and install PV in the Sacramento region. While this has had a positive impact on the SMUD customer, it does not help to build the SMUD-branded recognition as the utility leader in PV.

The ability of SMUD to entice hundreds of its customers to pay $4/month to host a SMUD-owned PV system is an outstanding comment on the positive image that many SMUD customers have of their energy provider. This type of participation and support for PV is needed throughout the country. A positive effect has been the ability of SMUD to utilize public goods funds to further buy-down PV systems to reduce the cost to the SMUD customer. The strong support and involvement of the SMUD customers to purchase PV systems under the PV Pioneer II program is another outstanding credit to SMUD.

3.4 PV Deployment Strategies – The Role of Electric Utilities

This section describes actions that an electric utility can take to significantly support the development of photovoltaic energy services and the local PV infrastructure. It is divided into two parts: Program Options and Potential Utility Benefits. The primary goal of these actions is increased market adoption. The secondary, but equally important goal, is that of infrastructure development.

3.4.1 PV Program Options

PV program options are utility strategies for expanding the residential, commercial, off-grid, and utility use of PV.

Generally, markets are developed by companies supplying products or services to customers who have needs. For PV, the need is still in its infancy. It is fueled by public policy, energy insecurity, customer desire for energy independence, and, most importantly, the need for clean, environmentally sound production of electrical energy. The need for PV is, to a lesser extent, being driven by a broad interest in distributed generation resources. Distributed generation resources are increasing as utilities and large energy users strive for economic advantages. Distributed generation resources provide local energy security, while reducing dependency on hard-to-expand transmission capacity.

Those interviewed as part of this project were, for the most part, unified in stating that the market deployment of PV must be led by system manufacturers, distributors, local sales, and installation businesses, while the utility plays a supporting role. Utilities are important as:

- Advocates for PV.
- The gatekeepers for interconnection and safety issues.
- Implementers of economic incentives such as buy-down incentives, performance-based incentives, and financing options.
- Facilitators of PV installations through the use of mechanisms such as net metering.

The role of utilities as a seller and installer of PV systems is difficult and it is probably better for the utility to support the PV industry with other types of programs. When utilities have branched out to provide home energy efficiency services in competition with local contractors, they have often encountered opposition from regulators, the competing contractors, and other business interests. The same or similar opposition has emerged when electric utilities sell or install PV systems.

SEPA recommends that electric utilities utilize the unique skills they have to communicate, finance, advocate, and provide incentives where it is economically attractive and/or legally required. A collaborative relationship with PV manufacturers, distributors, and installers is generally more productive than competition.

If a utility is to take on the seller and installer role, it is best accomplished through a subsidiary or affiliate.

Economic analysis has shown that customer-owned systems can show a positive net present value to the utilities with benefits offsetting the loss of revenue. As part of the SEPA project, the project team developed Report 1.2.2.3, *Economic Assessment of PV Deployment Strategies*, which is summarized in Section 1 of this report. Report 1.2.2.3 discusses in detail the net present value of various PV deployment scenarios.

Customer-owned systems are economically preferred to utility-owned systems, but program participants look to incentives and financing to make PV installation economically viable. The parties engaged in PV deployment strategies are encouraged to consider all PV benefits in a complete financial analysis, including the value of enhanced public image. In the end, all parties will justify their financial decisions based on a rational consideration of factors important to them, even if some of the factors themselves are not easily quantifiable.

SEPA recommends that utilities evaluate the tools discussed in earlier sections and in Report 1.2.2.3, to determine which tools can be useful in their regulatory, community, and economic environment.

When beginning program development, the utility should take the following actions:

- Perform market research to determine: (1) ratepayer interest in solar; (2) the services that the utility must provide in support of program participants; and (3) other actions that must be taken to broadly develop PV services.
- Determine the characteristics of the solar resource in the utility's service area.
- Evaluate the capabilities of PV manufacturers, local suppliers of PV equipment, and local or regional installation and repair contractors.
- Establish goals of the PV program that support the utility's critical business goals.
- Investigate potential partners that can potentially provide critical support to make the program more successful.
- Identify the costs and benefits associated with a PV program and its components. This may include avoided environmental, regulatory, and energy costs.
- Explore all program options, some of which are discussed in more detail later in this section, including green power sales, financing, marketing, use of state and national incentives, and demonstrating leadership through its own use of solar.

Potential partners who can support the utility's critical business goals may include state, community, business, financial, and environmental groups, as well as other utilities. Collaboration with other utilities may benefit all parties. Collaboration can range from joint or coordinated programs to mutual participation in industry action groups.

Implementation of a PV program will require the engagement of a utility's core capabilities, and may also require the development of new capabilities. The implementation steps that will require the use of core capabilities include:

- The development of a business structure, which may include any or all of the following: (1) the use of contracted services; (2) the organization of a subsidiary or affiliate; and (3) risk and liability management.
- The selection of contractors and partners, including possibly a third party for monitoring and performance evaluation of the utility and its partners.

- Market development, advertising, promotion, and communications.
- The education of local building code officials.
- The training and development of local trades and equipment distribution infrastructure with emphasis on contractor training.
- The creation of key trade allies.

Three items in planning and executing a PV program fall outside the normal development and implementation steps familiar in utility demand-side programs:

1. Monitoring and evaluation of installed PV systems.
2. Monitoring and evaluation of the PV program and all of its components.
3. Research, development, and demonstration (RD&D) of new system components, market development strategies, and communication tools.

If RD&D efforts are difficult budget items for a single utility, partnerships may be used to aggregate funds to address important issues. An example might be participation in an effort to develop new types of BIPV systems for use by residential production builders in the area.

3.4.2 PV Sales and Services for Customers

This section covers the direct sales of PV systems to customers by utilities and, more commonly, sales by a firm other than the local utility, but facilitated or assisted by the utility.

While "PV Sales and Services" implies that the utility may sell, install, and service PV systems, this will often not be the case. The utility, instead, will communicate, advocate, facilitate, offer its core capabilities, remove barriers, and work with public officials and private companies to stimulate the demand that will help drive down costs and create a sustainable market penetration of this technology.

SMUD has sold and installed PV systems during the PV Pioneer I and II programs. SMUD's leadership in this area has created excellent community awareness of solar energy in Sacramento. For a number of reasons, SMUD is moving away from direct sales to contractor-driven PV programs with SMUD in more of a supporting role. Interested utilities should begin their research by understanding the programs and lessons learned from SMUD's early efforts (see the details in SEPA's Report 1.2.2.1 *SMUD's PV Program and Sacramento Markets*).

PV Sales and Services – Residential PV

Based on residential program research, the following program development recommendations are made:

- Utility programs should support PV for use in new construction projects with production builders, in addition to retrofit projects.
- Contractor-driven programs are preferable to programs in which the utility sells and installs the PV system itself.

- Collaboration or partnerships with interested production builders can be an important, and possibly necessary, part of a PV program.
- Program staffing must be adequate and staff must be able to meet the needs of the more important market actors, beginning with production builders.
- Utility PV programs should support the development of BIPV roofing systems suitable for the local housing stock.
- With respect to PV systems installed at customer-owned sites, customer-owned PV systems are financially preferable to utility-owned PV systems.

These residential program development and implementation steps form the basis for the *Action Template for a Utility PV Program* presented at the end of this section in Table 5. This template, developed as part of this SEPA project, is relevant for all of the program options highlighted throughout this section. The focus of the remainder of this section will be the unique points that offer opportunities and benefits to utilities.

PV Sales and Services – Commercial Building Solar Deployment

Buildings with large, flat roof areas often have sufficient area to support PV systems with capacities exceeding 100 kW_{ptc}, and roof areas capable of holding PV arrays sized from 500 kW_{ptc} to 1 MW_{ptc} are not uncommon. Compared to the typical residential rooftop that can support 2 to 5 kW_{ptc} of PV, commercial-sector rooftops offer economies of scale for lower cost PV installations when measured on a dollars-per-kW_{ptc} basis. A leading solar company, PowerLight Corporation in Berkeley, California, has developed a fast-growing business specializing in large PV systems for commercial-sector flat roofs.

Public and energy policy makers may eventually view large building rooftops as clean electric generation sites and expect that they will be used as such. Beyond rooftops, some buildings in Europe have vertical architectural walls that could have been covered with marble or glass, but are instead generating electricity with PV on the south, and even east and west walls.

The utility, if it is to stimulate commercial-sector PV, may need to have an architect and a business analyst on staff to work with developers, builders, and building owners, creating an environment of knowledge, capability, and trust. LADWP has taken this approach in its commercial-sector PV program.

3.4.3 Potential Utility Benefits

Many of those interviewed as part of this project expressed the need for utility support of PV and provided examples of the corresponding benefits that utilities might obtain:

- The adoption of a leadership role in addressing customer interests, working toward a cleaner environment, and creating future energy pathways.
- Local business development and local control of generating resources.
- Avoidance of transmission difficulties.
- Improved customer services.

Utility-Owned PV Installations

Utilities can support the development of the PV industry by building, owning, and operating their own systems. Utilities can help increase PV sales volume for manufacturers, potentially reducing costs. Utility-owned PV installations increase the visibility of PV, indirectly marketing PV and increasing interest among potential buyers of PV systems. Utility-owned PV projects can also validate new designs and technologies, easing their entry into the market. In addition, utility-owned systems can be sited to support the distribution system and/or provide peak-period load reduction on utility-owned buildings.

3.4.4 Financing

Addressing the financing issue is one of the important steps in developing PV markets in a utility's community. Financing embedded in a home mortgage, or a financing instrument similar in cost and term, can make the payments for PV ownership equal to or lower than the value of the energy savings realized through utility bills. At today's prices for PV systems, state or local incentives are usually required to make this true.

Studies have shown the importance of low-cost, long-term financing for PV systems. Small improvements in interest rates can be, to some extent, as important as reducing the installed cost of PV. Utilities are institutions that have access to low-cost, long-term capital. SEPA recommends that utilities use this resource to provide attractive financing for PV. More broadly, SEPA recommends that utilities support efforts to establish PV financing programs throughout the nation.

SEPA recommends that utilities work with existing financial organizations as a first step. Banks and mortgage companies are accustomed to handling issues related to financing that are outside of those normally encountered by electric utilities. These include:

- Building liens.
- Owners who move.
- Property liability.
- Failure to make payment on the loans.

3.4.5 Renewable Portfolio Standards

Meeting state RPS requirements will lead utilities to utilize the lowest cost renewable energy options. Therefore, SEPA advocates[29] that an RPS must have a solar set-aside, or incorporate a multiplier to recognize that solar has added benefits to an RPS. Solar has added utility benefits because it generates electricity at the load, reducing T&D system requirements and line energy losses.

Experience in Arizona demonstrates the value of an RPS with a solar requirement. The two major IOUs in the state, Arizona Public Service and Tucson Electric Power, are building utility-scale PV facilities in the countryside near existing transmission and generation facilities at the

29. SEPA Policy Statement, http://www.SolarElectricPower.org/

rate of 1 MW or more per year. The utilities are reaping public relations benefits and helping the industry reduce PV costs.

Utility-Scale Solar Electric Power

This discussion covers the building of larger PV systems, defined usually as 500 kW_{ptc} or larger, that provide system benefits to the utility and may be feasible independent of an RPS. Benefits to the grid include voltage control and deferral of system upgrades.

Unless management has developed a clear economic analysis that includes the less tangible benefits associated with PV, the utility should not invest significantly in this area. Two guiding concepts have emerged:

- Customer investments in PV, possibly with a greater array of incentives and the "free" real estate of roof tops, are more economical, at least for the utility.
- PV is most advantageous when it is sited at the load being served, not remotely, as wind and smokestack resources must be sited.

Green Power Sales

SEPA recommends that every utility offer at least one green power option to its customers. Customers want the option to purchase green power, provided that the certification and authenticity of the program is clear. Since there is customer variety in any marketplace, leading utilities may want to offer more than one green product. There are many energy service and utility company programs to learn from. The U.S. Environmental Protection Agency has a program to promote leadership and sharing of information in the green power market. The alternatives to a conventional green-power program are premium cost green pricing and the sale of green tags. Such alternatives may be suitable for those who cannot take the electric service directly, such as tenants who are not billed for electricity.

Market research by the utility will be needed to:

- Determine ratepayer interest.
- Identify existing programs and define program components.
- Pre-sell some of the concepts to determine their effectiveness.

An important market research activity will be to learn the lessons from those utilities and energy service companies that have paved this already well-worn path.

Green power and green tags can be productive revenue streams for the utilities, making these programs quite valuable. Goodwill, without economic cost, is a resulting benefit and the learning experience will help the utility prepare for a solar future.

3.4.6 Template for Creating and Implementing a Utility Photovoltaic Business

The work performed in this project has resulted in the development of a template for utility action. This template is presented on the following pages. The details of template actions have been addressed in project reports, and are referenced in the template of Table 5.

Table 5. Action Template for a Utility PV Program

Creating and Implementing a Utility PV Business	
References refer to the series of reports produced as part of this SEPA project, unless otherwise noted.	
Phase 1: Research and Goals	
Market Research Investigate customer interest, existing PV infrastructure, and the potential for PV deployment. Customer Interest • Residential • Commercial • Industrial • Institutional Solar Power Penetration Limits • Load Shape • System Wide • Local Distribution • Solar Value for Peak Reduction PV Sales/Service/Maintenance Suppliers • Local • Qualified Bidders	**References** Vol 2, Section IX Vol 2, Section VIII Vol 2, Section VIII Vol 2, Section VII, VIII NREL Fuel From the Sky, 2002 www.nrel.gov Vol 6, Section III; Vol 2 Section V

Business Goals
Examine the broad goals of the organization and research how PV can be used to meet those goals:
• Profits/Surplus
• Peak Load Reduction
• Increased Grid/Customer Reliability
• Reduced Cost of Service for Certain Markets, including T&D upgrade deferrals
• System Characteristics, including voltage regulation and fault current protection
• Expanded Business and Revenue Generation
• Meeting RPS or Regulated Goal
• Image/Public Relations: Clean Air, Meeting Customer Needs, Stabilizing Costs, including:
  o Local
  o State/Federal
  o Among Investors
  o Competitive, Among Utilities
• Financial or Other Benefits to Participating Customers
	References
	
	Vol 3, Section III
	Vol 3, Section III
	Vol 3, Section III
	Vol 3, Section III
	
	Vol 3, Section II
	Vol 3, Section II
	Vol 3, Section II
	
	Vol 3, Section IV

Phase 2: Program Exploration	
Partners Investigate potential partners to support PV program. Partners may share costs or may provide marketing and technical expertise. Partners may include • State • Communities • Suppliers • Lenders • Economic Development Agencies, Local and State • Installers • Environmental Groups • Other Utilities	**References** *(all)* Vol 2, Section X

Cost Analysis
Analyze the costs associated with a PV deployment program. The following factors should be included in the analyses:
• Equipment
  o PV System
  o User Feedback Metering
  o Utility Performance Measurement
• Generation Gain/Revenue Loss
• System Benefits and Losses
• Environmental
• Labor and Staffing
• Government Incentives
• Utility Administration/Management
• Monitoring and Evaluation
	References
	(all) Vol 6, Section III
	(all) Vol 3, Entirety

Phase 3: Program Development	
• Financial Facilitation and Assistance Plan • Investigate available mechanisms to make PV more economic for the end user. The utility may want to provide these incentives for its customers, or it may seek the incentives to support its program directly. Financial incentives may include: • Rebates, by class, size • Production (kWh) or other incentives, by class, size • Mortgage loan program or other financing mechanisms	**References** *(all)* Vol 3, Section III

Program Options Investigate and select strategies for deploying PV. Program options may include: • Green Power or Green Tags • Bulk Utility Scale PV • Local Manufacturing/Jobs Creation Market sectors to be evaluated should include: • Retrofit Residential • New Residential • Commercial • Schools and Public Institutions	**References** *(all)* Vol 3, Section VI *(all)* Vol 2, Section VII-IX
Business Structure Determine the structure of the program and how the work will be accomplished. Work may be completed: • In-house • Using a contractor • Through a subsidiary • Risk/Liability Management will be an important consideration	**References** *(all)* Vol 1, Section II, VI
Contractor Selection Determine which components of the program are executed by contractors, and establish processes for selecting contractors. The following components are most likely to be accomplished through the use of contractors: • Marketing • Infrastructure development, including contractor training • Sales • Installation • Certification of installed systems • Performance assessment and commissioning	**References** *(all)* Vol 2, Section V, VI
Promotion/Market Development and Communications – Establish mechanism for raising awareness of the program and recruiting participants • Advertising • Press Coverage • Customer Mail • Local Fairs and Shows	**References** *(all)* Vol 6, Section III, Marketing and Outreach
Customer-Friendly Connection Determine strategies to simplify PV purchases for the utility customers. • Interconnection Policies • Paperwork • Fees • Net-metering	**References** Vol 6, Section III Vol 6, Section III

Phase 4: Evaluation and RD&D	
Monitoring and Evaluation Develop mechanisms to monitor and evaluate success of the program and the value in meeting the utility's goals, including: • A Baseline Program Database • Tools for Performance Monitoring Against Goals • Impact Evaluation • Presentations to Board, Stakeholders and Customers	**References** *(all)* Vol 6, Section VII
Research, Development and Demonstration Include components of research, development and demonstration to support growth in the PV industry and to ensure that the technology is developing to meet the utility's needs. Possible RD&D areas include: • Roofing materials and roofing systems • PV systems • Niche markets and new applications for PV • Marketing materials Cost-sharing opportunities for RD&D include: • Federal • State • Community	**References** *(all)* Vol 1, Section II

Source: Solar Electric Power Association.

4.0 Results, Conclusions, and Recommendations

PV is being used by utilities and their customers. Market development activities are underway, but incentives and awareness by both the utility and customers are needed. PV can provide value in strategic locations and can help a utility meet demand and protect the environment. SMUD has provided a wealth of information from its many efforts, and its examples can provide value to other utilities in California and throughout the nation.

The *Action Template* will provide value to utilities that are starting or expanding a PV program. There are several PV deployment strategies for utilities to consider. Continued cost reductions, product improvements, and new developments in application-specific products (BIPV in particular) will continue as this technology matures. This report identifies needed incentives and assistance from local, state, and federal governments. With appropriate utility interconnection practices, reliable PV products, and adequate marketing and sales, PV deployment can be a successful solution for specific utility and customer applications. PV can be cost-effective if implemented properly.

This study has drawn on all of the experience and resources that SEPA and TTC have developed since 1992 when the Utility PhotoVoltaic Group formed. It presents the best information for utilities, governments, and other stakeholders from a utility deployment and facilitation perspective. The energy service providers, electric utilities, and others serving customer electric energy needs are in key positions of influence for the development of this green, distributed generation resource. The *Action Template* presented in this report is the roadmap for utilities not yet fully engaged in solar businesses. The recommendations in the *Action Template* section address opportunities for each of the stakeholder groups to contribute to expansion of solar markets.

Utilities can be obstacles to customer connection of PV. SEPA hopes that the case has been made in this study for removal of obstacles and for the creation of incentives. Utilities can find profitable business opportunities that serve their customers' needs, and utilities can develop strategies that encourage customer investments in PV. Recommendations are presented that serve both utilities and their customers.

SEPA recommends that every electric utility have a solar strategy and this study can provide assistance and guidance for developing a strategy. This is beneficial for utility customers who want solar energy to be part of their energy mix.

4.1 Recommendations for Utilities

Based on data collected throughout this project, PV can provide value for electric utilities, regardless of regulatory structure and geographic location. Utilities are encouraged to explore the values appropriate to their own circumstances.

The following is rationale for SMUD's involvement in PV. Some or all aspects may apply to other utilities.

- **Reducing summer peak load –** Sacramento, like other areas of the country, has a severe peak load demand, straining the electricity system, and requiring resources specifically to meet these peak requirements. The output of PV systems coincides with a portion of SMUD's peak demand. Recent research suggests that PV can easily be combined with load management efforts to extend the benefit across the entire peak period. At eight hours, SMUD's summer peak period is longer than that of many utilities. Because of a large residential component, SMUD's system peaks at about 6 p.m., later than the peak of many utilities.
- **Meeting customer demand and providing customer satisfaction –** Due to concerns about California's electric system, there is substantial demand for PV in the SMUD service area as well as all of California.
- **Improving image and public relations –** Renewable energy, particularly PV, is viewed favorably by the public. Utilities can use high-visibility PV systems to raise awareness of their renewable energy activities, leading to an improved public image.
- **Maintaining local control of generation and avoiding transmission constraints**.
- **Supporting the distribution system.**
- **Creating local jobs.**
- **Meeting a Renewable Energy Portfolio Standard –** PV may become an important tool in meeting an RPS as the cost of PV declines. If there is a set-aside for solar, it will be an important component.
- **Growing the PV Market –** Involvement by the local electric utility can accelerate the development of local markets for PV.
- **Reducing Utility Cost –** Strategically located PV systems can: help with voltage control; replace long, lightly loaded distribution feeders; offset expensive peak energy; defer distribution circuit and substation upgrades; and provide other site-specific grid support.

SEPA recommends that all utilities implement a PV program, however limited or expansive. Utilities should:

- Understand PV technology and its roles and benefits in distributed generation and customer service.
- Demonstrate leadership for renewable, sustainable energy production in the community and among utility customers, obtaining recognition for utility actions that benefit the community.
- Build confidence among future PV users by providing technical knowledge, reliable system performance, procurement experience, and support for expansion of PV in communities.

- Improve PV system performance by applying the rigors of utility standards and address performance issues through system improvements and warranties.
- Help reduce PV system costs through volume purchases, standard system designs, and certified and trained contractors for siting and installation.
- Assist in building the local sales, installation, and maintenance infrastructure.
- Create incentives to improve the economics of customer-owned systems and work to make it easy for customers to use the incentives.
- Facilitate the availability of, or directly provide, long-term financing similar to a mortgage to make the expense stream for a PV system more closely match the utility bill savings.

A robust utility PV program includes:

- Working with builders to install PV in new construction projects.
- Facilitating PV sales targeting existing residential and commercial customers.
- Deploying large-scale, utility-size PV installations.
- Applying lessons learned from past programs to shape future programs.

Utilities should explore the use of all the tools discussed in this report and the other reports produced under this SEPA project.

As part of the program-development process, SEPA recommends that electric utilities perform the following actions:

- Perform market research to determine customer interest in solar, the various services the utility can perform, and actions it can take.
- Determine the characteristics of the solar resource in the utility's areas of interest, which could go beyond its own service territory.
- Develop an understanding of the capabilities available from local and national suppliers of PV systems.
- Develop PV strategy options consistent with the utility's own critical business goals.
- Investigate potential partnerships and collaborations that can provide critical support, including federal, state, community, business, finance, environmental groups, and other utilities.
- Develop the basic cost components of PV systems, program components, avoided environmental, regulatory and energy costs, and program management components, including monitoring of the program results.
- Work to develop the local infrastructure, including contractor certification and training.

- Develop the ability to inspect, commission, monitor, and evaluate PV installations. (SMUD separately meters all PV installations and performance data is collected as part of its normal meter-reading process.)
- Develop a performance database.
- Explore all program options, including green power sales, financing, marketing, use of state and national incentives, and leadership in the utility use of PV.

SEPA recommends that the utility consider the guidance listed below:

- Carefully design customer communications, simplified to facilitate decision-making, with customer-friendly installation processes and reduced paperwork.
- Build awareness and knowledge among builders and architects in the area, these being businesses that can have the largest impact on local PV penetration.
- Assist in the development of the local base of installers and service technicians, without which there can be no sustainable PV market expansion.
- Utilize good aesthetic design and products for high visibility and residential installations.
- Expand the use of LEEDs ratings as a way to promote PV and provide visibility for those builders that employ advanced LEEDs techniques with PV.
- Develop recognition programs for customers that purchase PV systems and provide feedback devices that demonstrate system performance.
- Utilize sound technical information and specifications in purchases and work with PV customers. Many examples are available on the SEPA website (www.solarelectricpower.org).
- Offer incentives based on system performance to encourage correct long-term system operation.
- Provide financing or facilitate financing with a local lender involved in the finance process.
- Partner with builders, developers, and the PV industry. The combination of PV with energy efficiency and Zero Energy Home/Buildings programs reduces utility loads.

Utilities need to generate internal benefits through their PV programs. Creating business value may require entrepreneurial skills and market-driven responsiveness to evolving business conditions, characteristics that may be outside the normal utility scope of work. Establishing a PV business subsidiary may be preferable. If so, it should be branded with the utility name but should have separate staffing, profit and loss responsibility, and performance metrics. Subsidiary operations may include one or more of the following:

- Sales, installation, and/or service

- Purchase aggregation with a mark-up as a reseller
- Consultant to customers
- Owner/operator

Each of the programmatic options may be exercised within the local utility's service area, outside the service area only, or both. A subsidiary may be difficult for some municipal utilities, but they can be created, with a defined return to either the ratepayers or the stockholders, depending upon the source of the "investment" funds and the regulatory requirements. The options listed above and the variations described herein may not be suitable or allowable for all utilities. Some public power agencies may not be able to establish such business enterprises.

4.1.1 Off-Grid PV for Utilities

Off-grid PV applications offer unique opportunities for utilities. The market includes remote residential, telemetry, communication, water pumping, lighting, cathodic protection, and small remote power applications. Such markets are here today, usually cost-competitive without subsidy, and are growing.

In these markets, SEPA recommends that the utility consider the use of PV for any of its own remote power applications. The utility is encouraged to facilitate information sharing to customers and other users. Based on remarks from several who were interviewed, SEPA does not recommend that the utility create a business in off-grid PV as there is a flourishing private industry serving these markets.

4.2 Recommendations for SMUD

One of the main objectives of this project was to examine the SMUD PV program, past and present, and provide recommendations on how to continue and expand PV efforts. While this next section pertains specifically to SMUD's PV activities, SEPA encourages all readers to review these recommendations for their own use. The activities of SMUD, although unique in the past, have applicability to other utilities and municipalities in California and other states. These recommendations are relevant to other stakeholders including the PV industry, installers, roofers, homebuilders, and commercial developers.

4.2.1 PV Product Needs for SMUD

SMUD and other solar energy service providers need fully performing modules, inverters, and suppliers that can produce reliable, acceptably efficient products at a volume price, with schedules that meet utility and builder requirements.

This study did not identify special PV product capabilities or differences for the Sacramento region that were unique or needed special attention. The need for low-cost PV systems, utilizing long-life, durable PV modules with competitive efficiencies, connected to a reliable, cost-effective inverter, and interconnected to the utility grid under simple interconnection processes is universal. Sacramento has no more and no fewer requirements.

SEPA recommends that SMUD continue the successful Energy Commission cost-shared ReGen program and continue the development and commercialization of those products that offer the greatest benefit for the SMUD region and distribution system load requirements.

SEPA also recommends that SMUD consider other partnerships with the

Energy Commission and others to bring new equipment to the marketplace. Additional technical validations of selected equipment developed under the ReGen program or elsewhere may be necessary to accelerate their commercial introduction.

4.2.2 SMUD PV Program

The following eight recommendations result from the analysis and experience embodied in this effort. They are presented in no order and may be implemented in whole or in part, depending upon SMUD's own assessment of priorities and customer value.

1. Capitalize on the SMUD utility PV leadership position: Drive PV costs lower through the following strategies:

- Broaden partnership programs to aggregate larger purchases of PV system components. Such leadership also has the potential to lead more rapidly to standardized PV designs. SMUD will need to consider the impact of its aggregated purchases on local component and system supply chains, the distribution networks of the manufacturers, and the role of local entrepreneurs who are building the PV sales, installation, and service infrastructure.
- Continue to share SMUD expertise among utilities, thereby increasing the efficiency and purchases from partner and non-partner utilities. The PV knowledge and experience captured from SMUD projects, TEAM-UP and this study is a commodity valuable to energy service providers at several stages of PV program implementation. Important experience and knowledge include: procurement; equipment characteristics and purchase criteria; siting (orientation, roof structure requirements); BIPV experience and value analysis; installation practices; operation/maintenance procedures; training of local inspectors; and repair/warranty processes.
- Consider leading or supporting the establishment of a national photovoltaic market expansion initiative. SMUD has the ability, with other SEPA members and national leaders, to create a utility-led initiative—with interconnection, education, and marketing, training and certification, and builder and developer components, as well as long-term goals for market expansion—that would dominate efforts to drive costs down in the United States. SMUD would not be expected to expend significant resources in the development of a broad national initiative but such an initiative would have a significant impact on reducing SMUD's future PV costs.

2. Develop a new strategy for module and inverter manufacturing in the SMUD region (recognizing the lessons learned from the CalSolar experience). Utilize the large market demand in the Sacramento region to provide incentives to manufacturers to site facilities in the area for fabricating large-scale PV system components sized to export to other regions and countries

(not small manufacturing facilities sized for only the Sacramento area market). The module production business model is not one of small, local plants but one of very large facilities capable of producing, hundreds of megawatts annually. The jobs from such large facilities would be economically attractive to the region. The economic development potential of expanded local sales, installation, and support infrastructure are also significant. SMUD may help create local land and tax incentives for the manufacturer. A purchase commitment may still be necessary to successfully implement this recommendation. SEPA understands the potential reluctance of the SMUD Board to become engaged in manufacturing again, and also recognizes the need of the PV industry to position plants consistent with a worldwide distribution strategy. Nevertheless, encouraging local manufacturing can help strengthen the local economy and PV infrastructure. This is an appropriate component of a utility PV program.

3. Continue and expand the PV Pioneer II program, deciding between the appropriate combination of two purchasing strategies. SMUD has developed a reputation and branded value in their Solar Program that their customers recognize and appreciate. In implementation of this recommendation, SMUD, or any utility, will need to recognize the role of the local PV entrepreneurs in infrastructure development, including the manufacturers' distribution channels. Expand the program, continuing to utilize contractors for installation and warranties, with one or both of the following purchasing strategies:

- **Purchase system components in volume.** Utilizing standardized SMUD PV system designs, purchase large volumes, in multiple stages (not a single year, but two or three years), of modules, inverters, and system installations based on the budget allocation for each of the three segments (residential retrofit, new residential, and commercial) through a competitive RFP process. Multiple vendor awards should be considered to reduce delivery risks.
- **Purchase turnkey systems.** Competitively purchase annual or biannual allocations of turnkey (designed and installed) systems purchased with either SMUD or Energy Commission-approved criteria for modules and inverters. This option is very similar to the early Pioneer I installation so all the lessons learned from those projects should be reviewed.

4. Offer some combination of rebates, financing assistance and performance-based incentives to help the customer see a cash outlay that is closer to the cash savings from the energy generated. Options include the following:

- **Create a new energy-production-based buy-down program for SMUD customers.** It is still very necessary for customer-owned PV (both residential and commercial) to have a buy-down, or incentive. European experience in payments for energy produced (kWh), and many of those interviewed in this project, suggest that SMUD move from a capacity-based (kW) buy-down to a performance-based (kWh) buy-down where the customer receives a rebate based on actual system performance. There are complexities to this approach and it may be preferable to offer a production-based incentive only on larger systems. SMUD's current commercial strategy to offer a supplemental Self-Gen

rebate fits well into this thinking. The incentive program in Massachusetts, for example, offers a rebate based on both capacity and performance, allowing the customer to recover some up-front costs while still ensuring system performance over time. One option identified in the current SMUD resource plan has a 4 cents/kWh incentive for customer-owned PV systems. European incentives have been significantly larger than this. SEPA encourages this rebate approach as it focuses on the performance of the PV system. It may be desirable to coordinate such a program with neighboring utilities such that a number of local utilities offer the same per kilowatt-hour incentive.

- **Separate from PV Pioneer II, create an open market buy-down program.** For customers who wish to purchase a PV system from local or other suppliers directly on the open market, offer a SMUD buy-down similar to the Energy Commission or CPUC buy-down. SMUD may want to offer a higher buy-down to help make PV more competitive with SMUD's low electricity rates. This could be a decreasing buy-down similar to the Energy Commission buy-down.[30] The supply of the PV systems could also come from any qualified (defined by SMUD, using the Energy Commission criteria) entity, similar to what is now done in the California IOU territories.

- **Offer, or facilitate a bank offering of, a new financing option for SMUD PV customers to allow the monthly payments for PV system purchases to approach the electricity bill savings achieved, thus accelerating customer purchase decisions.** For example, if allowed by regulations and corporate policies, SMUD or the financing organization could offer 30-year financing similar to a mortgage with easy billing so that the payments would approximate the utility bill savings. The program needs to be designed to recognize the mobility of homeowners which is one reason to prefer bank or mortgage institution programs. They are accustomed to dealing with title and lien issues.

- **Offer customers the option for a larger PV portion in the Greenergy program.** The current Greenergy program offers only a small amount of PV. This program could be expanded to allow customers to help fund SMUD and/or community PV projects. Customers could opt for either a monthly charge for PV installations (the current Greenergy charge is $6 per month) or could actually purchase the output (kWh) of the PV system in incremental blocks. SMUD could price this product such that the incremental cost to SMUD would be minimal.

5. Develop a new monitoring and evaluation program element to review progress in meeting corporate goals. This should include not only the technical performance of the PV systems, but also the progress in reducing costs, meeting customer satisfaction goals, reduction of SMUD peak load, impact on the SMUD image, and other business goals. Rigorous analysis should be conducted and the results should be presented to the SMUD Board, ratepayers, and other utilities to both recognize the accountability to stakeholders and to help other utilities learn from SMUD experiences.

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30. Interview results from this study indicate that many believe that the Energy Commission buy-down is declining faster than PV system prices.

6. Continue SMUD management of its successful Energy Commission cost-shared ReGen program. Participate in the development and commercialization of those products that offer the greatest benefit for the SMUD region. Many of the existing ReGen projects can benefit from demonstrations, expanded demonstrations, and continued development activities.

7. Look for additional opportunities to partner with the Energy Commission and others to obtain funding for follow-on efforts on several of the ReGen projects to bring the equipment to the market place. Additional demonstrations of selected equipment successfully developed under the ReGen program would further accelerate these technologies to market. Opportunities for funding from SMUD, the Energy Commission, and U.S. DOE should be explored. ReGen is unique and can provide value to the U.S. DOE and to the National Center for Photovoltaics at NREL.

8. Investigate off-grid PV applications for SMUD. Off-grid PV applications offer unique opportunities for SMUD. In these markets, SEPA recommends that SMUD be a user itself, and facilitate information sharing to other users. SMUD should not necessarily be a seller of off-grid PV products and services as there is a flourishing private industry already serving these markets. SEPA recommends that SMUD complement its image and expand the PV activities by demonstrating emerging off-grid applications and equipment; facilitating the customer interest and purchases of off-grid systems where cost competitive; and possibly partnering with or providing incentives for the private companies serving these markets.

4.3 Recommendations for Government

Policy Options to Accelerate PV Deployment — There are a number of policy options that SEPA recommends government, regulatory agencies, and financial institutions use to accelerate the development of PV markets beyond what would occur naturally in the marketplace. A majority of the individuals interviewed in this project identified the significant value of federal and state government assistance in the evolution of the PV marketplace. Federal market expansion policies, beyond R&D efforts, were identified and are outlined below. Government policies (either federal, state, or both) include:

- Tax incentives.
- Net metering requirements.
- Options to reduce the costs to customers, such as production (kWh) incentives, rebates, and availability of low-interest loans.

The financial industry can offer low-interest loans, mortgages that may have preferential rates for homes with PV, or simplified financing and payment mechanisms that recognize the reduced energy bills and, therefore, the reduced risk of inability to pay the mortgage. Electric utilities can also implement, or work with others, to facilitate these policy options.

Federal, state, and local government actions should be designed to build upon the SEPA PV value propositions listed below.[31]

- Economic Value – The generation of solar electricity coincides with the normal peak utility demand during daylight hours in many communities. It therefore mitigates peak energy costs, brings total energy bills down, and can, in some cases, reduce the need to build incremental generation and transmission capacity.
- Environment – PV-based electricity is environmentally clean energy.
- Resource Economics – PV is fueled by a free and abundant energy source, reducing the consumption of more limited fuel resources.
- Inflation-Proof Fuel – PV systems provide an energy resource with costs that are fixed at the time of installation. Customers of solar electric power can be assured that the costs of their energy will not change as a result of fuel increases.
- Building Materials Offset – BIPV can reduce the costs of roofing or façade building components, providing a reduction in overall building costs.
- Zero Energy Homes and Buildings – The combination of energy-efficient technologies and PV in homes and buildings optimizes the value of both. Expand the development of information and educational materials for builders and communities to convey the value of combining solar and energy efficiency in buildings. Well-instrumented and documented demonstrations of energy-efficiency technologies and building design elements in regional applications are needed.
- Infrastructure Reliability and Efficiency – PV can be sited at or near the electrical load, thereby freeing up utility investment in distribution systems and enhancing the reliability, security, and cost-effectiveness of the grid. PV can increase grid reliability, resulting in increasing value in the future as secure, reliable high-quality power becomes more valuable.
- Infrastructure Energy Security – Distributed power, like PV, generally offers security benefits due to the diversity provided by multiple generating sources. Distributed power means less T&D to disrupt, and greater security because on-site generation is harder to disrupt, is more stable, and is less brittle than full reliance on centrally generated power.
- Energy and Economic Security – A renewable resource such as PV reduces dependence on traditional central sources of energy and creates a source of energy secure from external supply interruption and price manipulation.
- Choice – PV gives consumers the power to choose the source of the electricity they use and to act on their stated preference for renewable energy.

31. Policy Statement of SEPA, November 14, 2002.

- High-Value Jobs – As a sophisticated solid state technology, PV offers the opportunity to build an industry of high-technology companies and jobs in science, engineering, manufacturing, and services.

SEPA suggests the following actions for government agencies at all levels:

Building Code Changes — Local, state, and national building code officials are encouraged to adopt building codes, standards, and siting regulations that take the potential installation of PV into consideration. These changes would allow building-integrated PV systems to be incorporated more economically into building design and construction.

National Interconnection Standards and Policies — SEPA recommends that there be national adoption of "A Position Statement on Photovoltaic Interconnection" that identifies the value of all electric utilities and other electric service providers implementing uniform, simplified interconnection procedures for PV systems. SEPA finds that four national standards—the Institute for Electrical and Electronic Engineers Recommended Practice 929-2000 and Interconnection Standard 1547, the Underwriters Laboratories Test Procedure 1741, and the National Electrical Code Article 690—are sufficient to form a basis for uniform, simplified technical interconnection guidelines. About 32 states now have laws setting interconnection requirements. SEPA supports the adoption of minimum federal guidelines and the adoption of state standards that are consistent with the SEPA policy.

Net Metering and Time-Of-Use Pricing — SEPA recommends federal and state consideration of uniform net metering requirements as an appropriate mechanism to encourage customer investments in solar generation systems. Some net metering rates understate the value of PV energy at peak periods of energy delivery. SEPA, therefore, encourages time-of-use pricing for larger customers, where the extra cost of time-of-use metering can be justified, and net metering for smaller residential and commercial systems, with eventual movement to time-of-use pricing for all customers.

Tax Credits and Other Incentive Programs — A 15% residential solar energy tax credit has been authorized in the recently passed Energy Bill, with a cap of $2,000. SEPA supports this 15% residential tax credit with eligibility that includes utilities and energy service companies that may make such investments. SEPA supports extending the production tax credit to include solar electric power and supports creative approaches to state and local government and utility-supported buy-down programs for PV systems. SEPA supports a 20% investment tax credit for solar electric systems that would stimulate business investments in PV systems and in solar manufacturing capacity.

Department of Energy Solar RD&D — RD&D plays a significant role in developing a business model that defines public and private roles for PV. The continued successful development of PV requires rapid continuous improvement in the quality and cost-effectiveness of the technology. A demand-oriented PV strategy will reveal other development needs, some of which are appropriate for RD&D and some which are more appropriate for competition in the commercial marketplace. SEPA supports a strong federal RD&D program to improve solar system efficiency and reliability, with continued emphasis on developing new lower cost PV materials, reducing

the manufacturing costs of system components, and developing manufacturing techniques that will lead to new building-integrated solar products. In 2003, SEPA recommended annual U.S. Department of Energy solar PV budgets of at least $100 million, with funding to include market development and education activities.

Department of Energy Solar Deployment — While federal research is developing new technology for solar electric systems, U.S. DOE must also stimulate the development of local infrastructures and customer, builder, local regulator, and others' experience to more rapidly expand the market base. The U.S. Department of Energy should provide targeted funding to community initiatives that build on successes in the market and emphasize participation by industry, government, energy providers, and financial institutions.

Federal Procurement — SEPA recommends that the federal government, as the nation's largest consumer of electricity, can and should procure PV systems for its own needs. Federal installations of PV increase end-user confidence in the technology to a greater extent than federal R&D or demand-side support. While investors are leery of any technology that the government supports for political reasons, they are more comfortable with technology that the government uses for its own needs based on its total value proposition. Federal installation of PV also provides high visibility for PV systems and an opportunity to educate the public about the benefits of PV. A successful federal procurement initiative would have the following characteristics:

- Expand the existing guidance of FEMP, GSA, and U.S. DOE and increase outreach and education to alert facilities managers to the cost-effective applications and leadership opportunities.
- Install PV in all applications where it is the best-value option.
- Require federal agencies to perform power procurement based on life-cycle cost analysis.
- Create specific program targets such as one percent by 2010, with 20,000 federal solar energy systems by 2010 at an average of 5 kW_{ptc} each.
- Aggregate purchases into high-volume long-term contracts, such as 10 MW_{ptc} per year for five years.
- Demonstrate emerging BIPV products and components of ZEBs.
- Look for tie-ins to high potential community and utility programs such that federal procurements leverage broader investments in PV.

Renewable Portfolio Standard — A Renewable Portfolio Standard (RPS) requires that a certain portion of the electricity sold by utilities and energy service companies be derived from renewable resources. More than a dozen states have adopted an RPS and several more are considering one. The approaches and details of RPSs vary significantly from state to state and among initiatives considered at the national level. The details can make all the difference.

SEPA recommends that when an RPS is being considered, it carve out a portfolio within the portfolio for a diversified range of renewable energy options. It should account for existing renewables and it should account for both distributed generation and central generation. One way to do this is provide a credit, through introduction of a ratio, e.g. 5:1, for PV systems connected into the distribution system as opposed to the higher voltage transmission systems. A balanced portfolio that recognizes the system and cost advantages of renewables sited close to customer loads is appropriate and gets closer to the correct-value equation. Then, as generation approaches the customer, a higher percentage requirement for the RPS is appropriate.

In some circumstances, renewable energy may not fit the utility's resource plans due to economic or resource availability reasons. SEPA recommends a creative approach to RPS legislation that would allow the local utility, in lieu of payment of a penalty, to fund a buy-down solar program that would encourage their customers to invest in solar systems. Thus, even in this situation, the market for PV would expand.

4.4 SEPA Recommendations for the PV Industry

Ratings and Performance — SEPA recommends that the utility and PV industry continue to utilize the PTC (PVUSA Test Conditions, see the *PV Overview* section of this report for details) rating criteria. SEPA also suggests the PV industry consider the PowerMark module certification for modules, a process that not only determines a rating for the PV module, but performs selected IEEE, UL, and NEC certification testing to validate the durability and reliably of the modules. SEPA also recommends that any buyer of a PV system require that the seller provide a rating of the system (preferably a PTC rating, see above) and a prediction of the kWh output from the PV system for each month for typical weather conditions at the location of installation. Reputable manufacturers or installers will be able to give a good rating and a prediction of the output expected during each typical month of operation.

Monitoring — SEPA strongly recommends that the PV industry develop built-in monitoring capabilities and low-cost readouts as part of the PV system for the benefit of PV owners. Any value analysis or payback calculation will need to consider the amount of energy produced. The ability to measure this energy output not only verifies that the PV system is operating as expected, but it can also identify degradation or problems that may require maintenance or repair. Monitoring provides an additional value. Due to the positive attribute that the PV system contains no moving parts and does not make noise, the only method to determine proper operation is to monitor the electrical output of the inverter. If the PV system is connected to a residential or commercial building under a net metering policy, the use of a separate kWh meter on the output of the inverter can easily and inexpensively allow the owner to determine the amount of energy produced during any period.

Marketing — Several of the interviewees discussed the process and materials that are used by the PV industry to market PV to utilities. Based on these discussions, SEPA recommends the PV industry review the marketing processes that are used by other small generation equipment manufacturers and distributors (fuel cells, microturbines, gas turbines, engine-generators, etc.)

and identify how the PV industry can attain a similar marketing level. The utility industry is a very large market for the PV industry and existing marketing and sales are viewed to be insufficient by many utilities. The ability of the PV industry to market their products to the utility industry has been an evolutionary process. There is ample opportunity for improvement.

Educating Utilities — This study has identified the additional value of PV, beyond the energy produced, to utilities. Educating utilities on these values is as much a task for the PV industry as it is for SEPA. The PV industry needs to understand the drivers in today's utility climate and be able to successfully market PV to utilities for their own use as well as their customers. There are lessons that can provide value to the PV industry. SEPA makes the following recommendations to the PV industry:

- Understand the value of utilities as a partner to create buyers groups and use bulk purchasing power to reduce the cost of PV.
- Provide learning tools to utilities based on the industry's successes, experiences, and approaches.
- Understand the value of a utility partner to reach the general public easily and provide access to a large population.
- Consider the sustainable market potential of utilities as they have the ability to make long-term commitments and large purchases of PV.
- Consider the marketing opportunities of utility-focused conferences, meetings, and exhibits.

Building-Integrated PV — SEPA recommends that the PV industry increase its efforts to work with architects and builders to develop aesthetically pleasing PV products that can be integrated into the building. New construction BIPV products for residential and commercial sectors can provide a great market expansion opportunity to the PV industry. Recent press has identified that some communities and homeowners do not allow solar installations on roofs as they are viewed as non-uniform, disruptive, and do not look pleasing. Changing these prohibitive codes and policies can be accelerated through more acceptable product configurations and designs.

4.5 Benefits to California

This project was designed to bring the experience and knowledge of SEPA to assess recent SMUD and California PV efforts. This assessment will be valuable to California for several reasons. The main value is the sharing of information obtained from numerous people in the PV industry and the SMUD PV program, combined with the experiences of past SEPA and U.S. DOE utility commercialization efforts. This information will allow the utilities and energy service providers in California to optimize PV programs in a more cost-effective manner to better serve their customers. This report is aimed at communicating the value of PV to the state's utilities, energy service providers, state and city governmental bodies, and general California electric customers. California has by far the largest and most significant PV market in

the United States, and the state is blessed with some of the best solar resources in the nation. With respect to electrical loads, California is intensely summer peaking and PV is the only renewable resource that can be sited at virtually any location on any utility's grid to shave peak load.

This report identifies and communicates the potential actions and activities that California utilities and energy service providers can undertake to develop successful PV programs. The report highlights the value and necessity of incentives to increase market penetration rates for PV. We suggest and recommend actions to a variety of California stakeholders that can grow PV markets, start and expand utility programs, and further the commercialization of PV in California and the rest of the nation.

This report and associated materials produced as part of this project will be disseminated to utilities and other stakeholders through SMUD's website. These materials will help to expand the California PV market and provide value to utilities and residential / commercial customers across the state. Lessons learned that are documented as a result of this project will help to optimize public goods funds applied to PV programs. California's electricity market has now stabilized from the chaos of the 2000/2001 time period, but customers are even more aware that they can demand and find cleanly-generated electricity, with availability and price stability.

Recent economic conditions within California will continue to impact many of the energy sectors, but the availability of buy-downs in California is a critical part for this market expansion. This study and report help to justify rebates and incentives for the next few years, without which the PV market in California will not continue to grow at a rate that best benefits the state.

The research team's efforts have identified the value of PV to California, in the form of clean air, less dependency on scarce water supplies, less noise, less transmission constraints, local T&D system benefits, locally sited generation, local jobs, and less dependency on imported electricity to the state.

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Glossary

AC	Alternating Current. A type of electrical current that changes direction at regular intervals. In the United States, the standard frequency is 60 hertz (cycles per second).
Amorphous Silicon	A thin-film, silicon photovoltaic cell material having no crystalline structure, manufactured by depositing layers of PV material on a glass or metal substrate.
ASES	American Solar Energy Society, a national organization dedicated to advancing the use of solar energy for the benefit of U.S. citizens and the global environment. ASES promotes the widespread near- and long-term use of solar energy.
BAPV	Building-Applied Photovoltaics, a term for a PV system that supplies energy to a building, but is not integrated into the roof. This term applies to many of the PV installations that use an offset mounting technique that has a space between the roof and the back of the module. This technique is commonly used to attach a PV array to an existing roof.
BIPV	Building-Integrated Photovoltaics, a term for the integration of electricity-producing PV into the building envelope, typically replacing conventional building materials. This integration may be in vertical facades, replacing vertical glass, or other facade material and in roofs and skylights, replacing roofing materials. The term BIPV also applies to a PV façade that provides additional energy benefits to a building, such as shading to reduce air-conditioning loads.
BOS	Balance of System, the components that comprise a complete PV system other than the PV module(s). The BOS includes items like the inverter, module support structure, wiring, conduit, hardware, protection equipment and switches.
CPUC	California Public Utilities Commission, which regulates privately owned electric, telecommunications, natural gas, water and transportation companies, in addition to household goods movers and rail safety.
DC	Direct Current. A type of electricity by which electricity flows in one direction and is usually a relatively low voltage and high current. Autos have a DC electrical system with a DC battery. Photovoltaic modules produce DC electricity.
DSIRE	Database of State Incentives for Renewable Energy at www.dsireusa.org.
Energy Commission	California Energy Commission, (http://www.energy.ca.gov/)
ERP	Emerging Renewables Program, of the California Energy Commission program whose goal is to develop a self-sustaining market for "emerging" renewable energy technologies in distributed generation applications. The

	program was created to stimulate market demand for renewable energy systems that meet certain eligibility requirements by offering rebates to reduce (buy down) the initial cost of the system to the customer.
Grid (Electrical grid)	An integrated utility system of electricity generation and distribution consisting of the wires, transformers, substations, power plants and control systems. The grid may also refer just to the transmission and distribution system, not including generation, particularly in regions where generation is owned by separate entities.
HVAC	Heating, ventilation, and air-conditioning system.
IOU	Investor-owned utility, owned by shareholders.
IREC	Interstate Renewable Energy Council, which supports market-oriented services targeted at education, coordination, procurement, the adoption and implementation of uniform guidelines and standards, and consumer protection. Their mission is to accelerate the sustainable utilization of renewable energy sources and technologies in and through state and local government and community activities.
kW	Kilowatt . A standard unit of electrical power equal to 1,000 watts, energy flow at a rate of 1000 joules per second. Subscript ptc: PVUSA Test Condition. Subscript dc: Direct Current. Subscript ac: Alternating Current. Subscript stc: Standard Test Condition.
kWh	Kilowatt-hour. 1,000 thousand watts acting over a period of 1 hour. The kWh is a unit of energy. 1 kWh=3,600 kilo Joules.
LADWP	Los Angeles Department of Water and Power, the largest municipal utility in the nation, supplying water and electricity to some 3.8 million residents and businesses in Los Angeles.
PCU	Power Conditioning Unit, or Inverter. A device that converts direct current electricity to alternating current either for a stand-alone system or to supply power to an electricity grid.
MW	Megawatt. 1,000 kilowatts, or 1 million watts, a standard unit of electric power plant generating capacity. Subscript ptc: PVUSA Test Condition. Subscript dc: Direct Current. Subscript ac: Alternating Current. Subscript stc: Standard Test Condition.
MSR	Million Solar Roofs initiative, with a goal to install solar energy systems (photovoltaics and solar thermal) on one million U.S. buildings by 2010. The Million Solar Roofs Initiative is designed to support states and local communities as they develop a strong commitment to the sustained deployment of solar energy technologies.
NEC	National Electrical Code, which contains guidelines for all types of electrical installations. The NEC contains Article 90, "Solar Photovoltaic Systems" which should be followed when installing a PV system.

NPS	National Park Service in the Department of the Interior, which preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations.
NREL	National Renewable Energy Laboratory, the primary federal laboratory for renewables, located in Golden, Colorado.
Peak Load	The highest electrical demand during a particular period of time. Daily electric peaks on weekdays usually occur in late afternoon and early evening. Annual peaks typically occur on hot summer days.
PG&E (Pacific Gas and Electric Company)	An investor-owned gas and electric utility covering much of Northern California.
PV (Photovoltaic)	The term used for the conversion of sunlight to electrical energy usually through the use of a PV cell, a semiconductor device.
PV Array	An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.
PV Module	The smallest environmentally protected assembly of solar cells.
PV System	A complete set of components for converting sunlight into electricity by the photovoltaic process, including the array and balance of system (BOS) components.
Public Goods or Benefits Funds	Public Benefit Funds are state-level programs usually developed as part of a utility restructuring process to continue support for renewable energy resources, energy efficiency initiatives, and low-income support programs. These funds are sometimes called a *system benefits charge*. Such a program is most commonly funded through a consumption charge to all electric customers, e.g., 0.2 cents/kWh. Examples of how the funds are used for PV include: rebates on renewable energy systems; funding for renewable energy R&D; and development of renewable energy education programs.
REC	Rural Electric Cooperative, more than 1,000 customer-owned rural utilities that serve more that 36 million customers in 47 states.
RPAC	ReGen Program Advisory Committee, the independent committee selected to guide and advise the SMUD/Energy Commission ReGen Program.
RPS	Renewable Portfolio Standard, a requirement that a certain percentage of a utility's overall or new generating capacity or energy sales must be derived from renewable resources. For example, one percent of electric sales must be from renewable energy. The term "set asides" is frequently used to refer to an RPS in which a utility is required to include a specific amount of a certain

	renewable technology (such as solar).
SDG&E	San Diego Gas &Electric Company, an investor owned gas and electric utility covering much of the southern part of California.
SCE	Southern California Edison, an investor owned electric utility covering much of the area around Los Angeles and the south central portion of California.
SEPA	Solar Electric Power Association, a collaboration of utilities, energy service providers and the photovoltaic industry working together to create and encourage commercial use of new solar electric power business models. SEPA helps to establish standards for photovoltaic systems and their interconnection to the utility grid, hosts cross-industry workshops, and manages educational and outreach campaigns (www.solarelectricpower.org).
SFPUC	San Francisco Public Utility Commission, a department of the City and County of San Francisco that provides water, wastewater, and municipal power services to San Francisco.
SMUD	Sacramento Municipal Utility District, the municipal electric utility in Sacramento, California that provides electric power to Sacramento County (and a small part of Placer County).
SOD	Sustained, Orderly Development. The term given to a set of efforts by SMUD to further the commercialization of PV. This term sometimes used SODC (Sustained, Orderly Development and Commercialization).
SPS	Solar Power Solutions. SPS was a project funded by the U.S. Department of Energy and managed by the Solar Electric Power Association (SEPA). SPS was a broad effort created to address barriers to commercialization, such as the development of local PV infrastructure, financing mechanisms, and education and outreach. SPS focused on collaboration of the PV industry, energy service providers, state and local government agencies, and other PV stakeholders.
STC	Standard Test Conditions, under which a module is typically tested in a laboratory. The conditions include a cell temperature of 77°F (25°C), and an irradiance of 1,000 watts per square meter.
TEAM-UP	Technology Experience to Accelerate Markets for Utility Photovoltaics, a SEPA-led, TTC-managed program that utilized $15 million of Department of Energy funds to cost share over $75 million of PV installations in the US. Over 1,100 PV systems were installed in 38 states over a 5 year period.
TTC	Technology Transition Corporation, a Washington, DC, western U.S. and European consulting firm that managed SEPA (formerly the UPVG) from 1992 through 2002 (www.ttcorp.com).
Utility-Interactive Inverter	An inverter that can function only when tied to the utility

	grid, also called a grid-tied or grid-connected inverter.
UPVG	Utility PhotoVoltaic Group, the former name of SEPA.
UPEx	The term use for the annual meeting for SEPA, the Solar Electric Power Experience Conference and Technology Exhibition,until 2004.
U.S. DOE	U.S. Department of Energy, whose strategic energy goal is to protect our national and economic security by promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy.
W	Watt. The rate of energy transfer equivalent to 1/746 horsepower or one Joule per second. Subscript ptc: PVUSA Test Condition. Subscript dc: Direct Current. Subscript ac: Alternating Current. Subscript stc: Standard Test Condition.
ZEB or ZEH	Zero-Energy Building or Zero-Energy Home, a building or home that combines high energy efficiency designs, appliances, and equipment with renewable energy to produce the energy needed to run the building. The concept is to annually, generate all the energy needed to run the building from on-site generation, and PV combined with solar thermal is the generation source of choice.

For a complete glossary of energy terms see the Energy Commissions **Consumer Energy Center Glossary** *at:* http://www.consumerenergycenter.org/glossary/index.html

Appendix A
Task Force Members

Task Force Members

Five members of the SEPA Board of Directors served on the Task Force:

* Matthew J. Cheney, Chief Operating Officer, Nuon Renewable Ventures USA, LLC

* Angelina M. Galiteva, former Executive Director, Strategic Planning, Los Angeles Department of Water and Power

* Eva Gardow, Project Manager, First Energy

* Ernie Palomino, Senior Principal Research Engineer, Salt River Project

* Bob Parkins, former Energy Services Manager and Solar Photovoltaic Program Manager, Western Area Power Administration

Staff of Technology Transition Corporation:

Steve Hester, Technical Director

Tara Willey, Project Coordinator

Jeff Serfass, President

Andrew Cotter, Editor