Performance Based Incentives for Photovoltaics Deliverable 1.1: Literature Search Summary Report—Overview

By Sackheim Consulting/Local Power Team
December, 2004

For Sacramento Municipal Utility District
RFP: 40512CJB

Performance-Based Incentives for Photovoltaics

Summaries of Literature

December 28, 2004

This paper begins with an outline of the different topics covered by the articles reviewed. This is divided into the same three sections as review sections: 1) American literature about Performance-Based Incentives (PBIs) and system performance, 2) the German programs, and 3) the value potential for photovoltaics. Each of these has discussion topics and some analysis. Important topics include: program financing, the level of payments, administration, metering, target markets and program goals.

A topic that several analysts have considered is the idea that payments over time are worth less than up-front payment. The diminished worth is called "net present value", and is assumed to work like an interest rate in reverse. Those who take net present value into account assume that the sum of future payments over time should be more than the comparable upfront payment to make up for the diminished future value of money. We believe that program elements, such as low interest loans and risk transfer, can counter this effect.

Critical elements of any program include:

- Simplicity of administration so that it does not become a barrier to success or a major expense.
- Accurate, revenue grade meters which are centrally monitored by modern communication systems
- Clear definition of goals, which must be accepted and implemented by SMUD, industry and participating customers
- Targeting of the most cost effective PV projects, which is broadly agreed to be in the commercial sector.
- Clearly addressing unresolved tax questions, such as the taxability of rebates, PBIs, local taxes, etc.

<u>1) American PBI and PV System Performance Literature</u>

The next section contains reviews of the literature itself. The first two articles, by American writers, deal with the design and benefits of Performance-Based Incentives.

Kenneth Starrs, the author of the first article, is perhaps the leading advocate in the US for this type of program. Starrs coins the term "Capacity Based Incentive" (CPI) for Buydown programs that pay against upfront capital costs. He says that capital subsidies make sense for an untested technology where there is high real or perceived risk. Performance incentives are appropriate when there is a certain level of trust in the performance, which happens as a technology develops a track record. The perceived risk must be paid for with a premium above the cost basis for the PBI. He recommends a PBI program with payments over five years, at a rate two to four times residential electricity rates, to minimize the risk element as well as the loss of net present value as payments are spread out into the future. Mr. Starrs also insists on the importance of metering the PV systems, but proposes what is (in our opinion) an archaic system of customer self-reporting and random on-site audits.

The second article examined the economic implications of PBI programs. It concludes that there a commercial PBI can save between 10 and 80 percent of program funds when compared to a Buydown. They authors also analyzed optimization and breakeven times for a PBI when compared to an equivalent amount of Buydown money paid upfront. They show how PBIs can, remarkably, also achieve faster returns than a money paid upfront. This is due to the significant tax savings.

The third article, written in 2002, reads almost like a laboratory experiment. It was about photovoltaic programs in Pennsylvania and Massachusetts, which were then the only two in the US to base payments on system performance. These were both hybrid program with an initial large Buydown, followed by a performance payment(s). In one program a very small payment was made to incentivize the installer. Targets were established for performance in both programs, but they had a different proportion of the payments set to reward performance. The Pennsylvania program had fixed total maximum that ranged between $.45 and $2 per watt, which decreased as the system size got larger. This was paid at the end of a one year period. The Massachusetts program paid a lower rate, but paid it every quarter over a three year period. The total amount was worth $1.50 per watt no matter what the system size. The Massachusetts program had almost all systems meet the performance goal, while the Pennsylvania program fell significantly short. This is all the more remarkable in that the Massachusetts program actually had a higher goal, while both states have similar solar resource.

An alternate, auction style incentive implemented in California and Pennsylvania is investigated by the LBL team. These show the importance that program structure and criteria have for a successful outcome. The Pennsylvania program had firm performance targets and required strong industry commitment, while the California program allowed participants to opt out midway through will little penalty and had numerous problems finding participants due to the energy crisis at the time. The result was that Pennsylvania's program was much more successful.

A few of the articles examine the US Buydown programs and how they rate on performance in a number of ways. Almost all American programs give rebates based on the purchase cost, irrespective of performance. On the other hand, the introduction of new payment systems in this country is very focused on improving performance. In a sense this is odd, because there is very little evidence one way or the other about performance of PV systems, and to what degree (or even whether) they can be improved. The reviewed articles provide some of the few clues available. One study of California PV systems showed significant performance problems, with an average shortfall in expected output between 25 and 33 percent. This study is reviewed by two authors, and is cited by the California Energy Commission (CEC) as justification for their PBI program.

One of the documents reviewed is the CEC's own pilot PBI program, which sets a payment level of $.35/kwh over a three year period. There is no loan or even financing assistance, no targeted market sector, no upfront rebate, no aggregation of purchasing power, no coordinated program planning or implementation, and no criteria for performance. Most commentators thought the program would be inadequate.

German PBI Programs

By contrast, the German system is a high fixed payment per kilowatt-hour over 20 years, tied to a generous loan program. Even though one might think that the primary motive for this is performance, in fact the payments are set up simply to cover the costs of PV systems. A tiered structure insures that small residential customers higher unit costs are covered. The German program has evolved through several stages, the first being similar to American net-metering. The second program was set up by a number of cities in the mid 1990s, and had payments over a dollar per kilowatt-hour. This was followed by the Hundred Thousand Roof Program and Renewable Energy Law, and the current (2004) feed-in tariff. These are motivated by national energy security, as well as global concerns about energy wars and climate change. The Germans are most interested in accelerating development of a large PV market, and have succeeded. With hundreds of megawatts of new installations every year, they have multiplied their market tenfold in the last six years, and now constitute a quarter of the world's total PV market.

PV Value

The final section deals with the important question of the value attributable to photovoltaics. One crucial problem for PV power is its high cost, and any PBI program must somehow justify this allocation of resources. There is a significant body of literature that ascribes value to photovoltaics, but less that attempts to quantify it. Two such efforts are summarized here. One of these is by a pair of analysts who attempt to quantify grid support and other values for Southern California utilities. They found PV to add about 2 to 5 cents/kWh. A third article is referenced that takes a more proactive approach of not simply ascribing value to PV, but actually attempting to enhance it by incorporating Demand Side Management into the PV installations.

Performance Based Incentives for Photovoltaics Deliverable 1.2: Industry Expert Interviews Report—Overview

By Sackheim Consulting/Local Power Team
December, 2004

For Sacramento Municipal Utility District
RFP: 40512CJB

Performance-Based Incentives for Photovoltaics

Overview of Interviews with Industry Experts

December 28, 2004

This research into Performance-Based Incentives (PBIs) approaches the topic from several different directions. Setting of incentive levels and program elements must be done with a careful eye toward market conditions in the photovoltaic industry on the one side, and actual performance of PV systems on the other. Yet each of these can be further analyzed into the roles that different people play in the PBI transaction. In general, system installers/integrators are most interested in and able to discuss performance incentive structures, while manufacturers are usually one step removed from this unless they also act as integrators.

Executive Summary

The Executive Summary draws mainly from discussions with Integrators. It points out two different structures for long term performance contracts, and ownership options under a performance system. These are identified as Design, Build, Maintain (DBM), and Owner Operator (OO) structures. The two systems create different interests, beneficiaries and pricing structures for a PBI program. Each system is used by different integrators.

Under a DBM arrangement, a contractor would have a fairly standard role of building PV systems, with the addition that they would also be responsible for long-term maintenance. The PBI is paid to the SMUD customer/owner, who is thus the recipient of the main incentive. This creates a bit of a disconnect between who gets the incentive and who is responsible for performance. On the other hand it allows for the lowest cost for PV.

An OO arrangement means that a third party owns and operates the PV systems, and essentially borrows or leases the rooftop or ground space. The OO party is directly responsible for the PV systems and is the direct beneficiary of payments. This creates the strongest possible motive for performance. On the other hand, there is also a need to offset all business risks and to generate a profit. This raises the cost considerably.

Industry Interviews

The next two sections cover details of interviews with PV panel (Section A) and inverter (Section B) manufacturers. These interviews concern mainly the aspects of a PBI program that would affect them. The topics covered include leading products, market conditions, manufacturing capability, lead time to deliver products, etc. PBI program topics were discussed when these were relevant. Manufacturer information is relevant to a PBI program for several reasons. Some of them, as mentioned above, are integrators or have staff that have extensive experience and interest in subsidy structures. Beyond this, however, manufacturers often have insight into PV performance issues: products that have special features, price flexibility, etc.

These constitute a basis for "wiggle room" where competition and the market can offer variation in performance or price. A third major question is the feasibility and timing for implementing a PV program on a large scale, and whether these could deliver savings for a PBI program.

In general, there was broad agreement that the market for PV panels is very tight right now, with resulting higher prices and limited room for negotiation. All manufacturers are attempting to ramp up production, some even doubling over the next year or so. Given a market expansion of 35 percent, we believe that they should easily catch up within this time frame, with possible over-capacity 1 - 1 ½ years from now. This should provide a good entry point for a significant new PV program.

Interviews with Integrators

These discussions ranged from installed system prices at different scales, to recommendations for financing and maintenance agreements. Integrators can often secure financing and some promise relatively quick payback periods for commercial buyers. These payback periods are conditioned upon tax write-offs and generous rebates, and can be accelerated further by including an energy efficiency/conservation component. Integrators are obviously favorable to the type of program/financing structure that they offer. On the one extreme, recommending the DBM model, is Sunpower and Geothermal, while on the OO side (third party model) is SunEdison. The OO models are set up to be competitive with delivered power prices, and assume an escalation over a long term. These financing schemes find low cost capital from investors who can take the tax benefits of the PV system, and require significant rebates to be successful. The profit is generated by trading renewable energy credits (RECs) on the PV power.

Integrators agree broadly that significant benefits accrue to going to a larger scale, both for individual commercial installations, and for a PV program as a whole. They also use (and are willing to use) creative solutions to increase output and improve the cost/benefit ratio. One industry spokesperson stated that SMUD low customer rates "at 8 cents per kilowatt-hour" is difficult for PV to compete with. Another industry spokesperson suggested that SMUD create a Time-of-Use rate structure to more nearly match PG&E's. Finally, there is also broad agreement that long term O&M contracts are viable for 20 to 25 years without difficulty; some already offer this.

Interviews with Nonaligned Experts

We conducted interviews with five experts who act principally in an advisory capacity to the solar industry. All were quite enthusiastic about SMUD creating a PBI program and offered a number of valuable recommendation. Three of these thought that the commercial sector offered the best opportunities, while a fourth suggested it is the proper successor to PV in the residential sector.

Dr. Aitken, author of a study for SMUD's solar program a few years ago, believed that the value of PV to the grid system should be adequately evaluated. He said it is essential to get the whole utility on board for this task, and account for all the PV systems installed, which has not been done. His study showed a natural market succession of PV applications from residential to commercial, substation and neighborhood, and lastly central generation. This accords with the value of generation at each point, with the highest value going to residential delivered power. He also believes in the value of zero peak energy homes.

Dr. Kammen of UC Berkeley recommends an array of policies designed to address the perceived high cost of photovoltaics, which he sees as a principal market barrier. His recommendations include building large-scale commercial PV systems, large scale contracts, and the use of clustered installations if it can be simplified. He recommends long-term (30 year) PBI payments to lower the cost premium, and to bring PV into line with current peak electricity prices.
Tor Allen, director of the Rahus Institute, believes PV should be integrated into the normal way power is purchased. He warns about heavy paperwork in a payment program costing a lot of money for installers. He says that PBI payments are of limited term (up to 20 years), and should be supplemented after that by net metering. Mr. Allen's also suggest that a premium value be given to PV systems in areas with constrained grid resources.

Tom Starrs, author of several articles on Performance Based Incentives, feels that one of the greatest advantages of a PBI program could be its ability to roll out a lot of PV quickly. Mr. Starrs suggested a dual tariff systems which depends on which side of the meter the PV systems is wired into: a low tariff on the customer side, and a high one if it is on the utility side. He cautioned that too long a payout period could jeopardize loan availability, and urges that revenue grade meters be installed to monitor PV systems.

Ryan Wiser stated that if the goal is improved performance, one should expect this more in the residential than the commercial sector. He argues that the commercial sector likely already has high performance, since it "motivated by best management practices" to optimize investments. Mr. Wiser makes the crucial point that a good loan program allows for a large extension of the PBI payment term. The PBI needs to be a better value than a competing Buydown, with two premiums: one to adjust for net present value, and another to compensate for "risk". The analysis of the premium value for PV should be addressed to those making policy, but not complicate the payment system itself. He also advised that tax policy be fully investigated before proceeding.

Performance Based Incentives for Photovoltaics
Deliverable 1.3: Program and Program Elements Report

By Sackheim Consulting/Local Power Team
January, 2005

For Sacramento Municipal Utility District
RFP: 40512CJB

Caveat and Disclaimer

This document contains references to tax policies. Relevant general information regarding current tax laws has been presented to the best of our ability, but the applicability of these laws depend on many factors such as tax bracket, profits and losses of a business in a given year, and future changes in tax law. Taxable income and deduction eligibility are also subject to rulings and decisions by the IRS, California Franchise Tax Board, and the courts. We in no way certify the exactitude or specific applicability of information regarding tax policies and their impact, nor are we offering specific tax advice to any party. All information and recommendations given with respect to tax issues are model assumptions which should be referred either to the IRS, a professional tax expert, or other appropriate taxing authority for verification of tax law and applicability in particular circumstances.

Table of Contents

Performance Based Incentives for Photovoltaics
Deliverable 1.3: Program and Program Elements Report

Executive Summary

Overview

SMUD's design for a performance-based incentive will likely involve some variation of the German/European Feed-in Tariff. This design can take a few different forms, which are outlined in this report. A Buydown does not protect SMUD and its customers from paying for inefficient systems, nor does it create an incentive to keep PV systems in working order (or even keep them installed if properties change ownership). A properly designed PBI program will create a model performance level; if it is exceeded then the owner has a chance to make a profit, if the performance falls short then they will not fully recover their costs. The program should create competition for the PV industry to improve component and system performance.

A PBI program spreads out incentive payments over time, lowering the annual budget impact on SMUD for each installed megawatt of PV. This should allow for a much faster scale-up on a limited budget than would otherwise be possible. It has taken 20 years for SMUD to build up 11 M W of installed photovoltaic capacity. We believe that it should be possible to double this figure in just a few years without significantly straining budgets with an effectively designed PBI program. The source and routing of funds will depend on how the program is structured, but the alternatives presented here are structured to be affordable.

There are several vital program elements for making photovoltaics affordable and incentivizing more development. One is to implement individual PV systems at a large enough scale so that the price per watt will be lowered. Another is to take advantage of generous Federal and California tax benefits in a way that does not waste rebate dollars, as current programs do. Another is to insure the long-term performance of PV systems with an effective monitoring and O&M program. When these are combined with low or zero interest loans, the PBI premium of PV power over delivered electric rates required for an effectively incentivized PBI program can be minimized, thus more efficiently utilizing SMUD's PV budget.

All these elements, and others described in this report, can meet significant goals of the PV program and are consistent with many of SMUD 's goals and values as a whole. The consistency between SMUD's stated solar principles, objectives and strategies and the goals and objectives of a PBI pilot program will be explored in a future deliverable.

Annotated Outline of the Full Report

1. Introduction

The introduction to the report describes how feed-in-tariffs are the basis for understanding all variations of performance-based incentives (PBIs). Supporting program elements, such as adequate scale, improved performance and cost reduction, are essential components of a successful PBI program.

2. Eleven Goals of a PBI Program

This chapter discusses eleven goals of photovoltaic programs. Clarity with regard to goals is crucial for constructing program elements and for judging program success. This analysis shows how goals for photovoltaic programs span a remarkably large range. Goals provide a framework for viewing from different angles the motivations that can guide PV programs, and will specifically guide the development of this PBI pilot program. Getting PV systems to produce more electricity is one important goal, but so is getting more performance for each dollar of PV program funds. Any program is inevitably going to be measured by marketing standards (e.g., how much PV was installed), as well as the cost of electricity produced. A clear understanding of goals is essential for achieving them, while a range of desirable goals opens up more opportunities for success.

3. Typology of Performance-Based Incentive Programs

This chapter describes the various types of performance based incentives that have been developed over the years. Performance Based Incentives for photovoltaics have become identified in the US with a premium payment per kilowatt hour for electricity production. Yet quite different systems have been used which involve performance, including: net metering, wholesale purchase prices, kilowatt-hour tax credits, hybrid payments and performance standards. Each of these has something important to contribute to a good PBI program.

4) Elements of Performance-Based Incentive Programs

Chapter Four in the report presents the various program elements found in PBI programs as well as elements in non-PBI programs that seem relevant. The elements of a PBI program considered here are: a) PBI construction (e.g.., straight feed-in tariff, premium value payment, hybrid payment, etc.), b) fund allocation (who gets paid and who pays it), c) payment amount, d) term, e) loan/financing, f) distribution of risk and responsibilities, g) goals, criteria and standards, h) metering, i) market sectors, j) tax cost and benefits, k) allocation of value, l) administration and m) integration of PV. These and other program elements will be discussed further in later deliverables.

5) American PBI Programs

This chapter reviews several American incentive programs in Massachusetts, Pennsylvania, and Connecticut as well as the smaller coop programs in those states. All of these are hybrid payment systems which offer an upfront rebate along with subsequent performance payments. There is also a description of the new PBI incentive program proposed by the CEC in California.

6) German and other European PBI Programs

A detailed description is presented of the programs in Germany, as well as a brief overview of the range of other feed-in tariff programs in other European countries such as Spain, Portugal, Italy, Switzerland, Austria and the Netherlands.

7) Value Criteria

Chapter Seven summarizes the various elements relevant to the design of a SMUD PBI program that add value to photovoltaics, including peak power, distributed generation, and the potential for adding these values in an active way. The focus is not on measuring values or "stacked benefits" of PV, but creating the basis for designing and evaluating program elements, payment levels and allocation of benefits.

8) Conclusion

A Performance Based Incentive can shift SMUD's relationship to photovoltaics from a subsidizer role to a purchaser role while simultaneously honoring SMUD's core values and achieving many of SMUD's goals and objectives for solar energy. Photovoltaics can:

- Contribute to SMUD's RPS goals
- Provide the "stacked benefits" of distributed energy
- Provide a source of locally owned and locally sited generation
- Provide hedges against fuel price risk and low hydro availability

Photovoltaics has the potential to achieve many of SMUD's solar energy goals while minimizing major risks that could challenge SMUD. A well-designed PBI Program has the potential to provide major benefits to SMUD, consumers, health and the environment while allowing SMUD to pay only for PV system output. By providing incentives for performance, taking advantage of tax benefits, providing low cost financing, and building large-scale PV projects, SMUD can achieve the goal of lowering the cost of PV electricity while building up a secure, clean, local and affordable source of energy.

1. Introduction

A. The Challenge: A Competitive PBI

In order to continue its leadership in solar power, SMUD is considering Performance Based Incentives (PBIs) to stimulate the growth of the PV market in its service area. PBIs are an alternative to the current Buydown programs which pay a large incentive to customers when they purchase of a PV system. Because PBIs are paid out over a period of years, they offer a major benefit to oversubscribed PV incentive programs with limited cash flow. PBIs offer more a number of other benefits as well. SMUD is seeking to foster the development of a self-sustaining PV market in Sacramento while adhering to its own business aims. A properly designed PBI program has the potential to fulfill SMUD's goals to:

- Generate the greatest amount of PV electricity for the least outlay of incentive funds
- Accelerate PV market penetration in high growth markets; to shift the focus to performance rather than capacity
- Redefine SMUD's role in PV from a steward and subsidizer to a purchaser of either system output or the premium value of renewable power

Accordingly, our analysis suggests that SMUD's Performance Based Incentives (PBI) program will likely be a variation of the tariff systems developed largely by European governments. These tariffs are created under the principle that photovoltaic system owners be treated in a similar way to conventional power plant owners who enter into power purchase agreements with a utility or electric service provider. Like merchant generators, customers feed the electricity into the public grid and are guaranteed a payback rate that allows them to finance and to maintain their PV systems. Thus, like other conventional resources, the costs for PBI photovoltaics are included in the electric rates such that all utility consumers virtually purchase the photovoltaic capacity installed. Such a purchase can take several forms that will be explained and illustrated with existing programs; the principle types are:

- "Feed-in Tariffs" of the German model, which would be a direct power purchase by SMUD
- "Premium Value Payments" which covers the excess cost of PV over the delivered cost of electricity, for which SMUD could get renewable energy credit
- "Hybrid Subsidy Payments" which combines an upfront rebate with ongoing payments for electricity production

With a properly designed program, a large commercial or industrial firm considering a new PV installation can readily calculate the cost benefit of such an installation. Also, SMUD can estimate the value of avoided energy supply purchases and infrastructure investment to accommodate the utility's anticipated electrical power and renewable resource needs.

B. PBI Payback: Lower Cost, Better Performance

The principal benefits of PBI over a Buydown derive from a fundamental realignment of economic incentives and risk management. Buydown programs give customers a fixed payment per watt of capacity, and have no penalty for systems that are under performing or even taken down. Rebate money is effectively wasted in these cases. In contrast, PBI PV customers or developers who build more efficient, high performing installations than anticipated by the utility's optimized model system have the opportunity to make a profit from the tariff. Customers or developers whose systems are more expensive than the optimized model will not fully recover their costs. Thus, PBI tariffs reduce utility risk associated with photovoltaic subsidies. At the same timer PBIs encourage needed competition between both wholesalers and installers of PV systems to lower the cost of installed capacity, a benefit to the customer.

PBIs also provides incentives for participating PBI customers to ensure system performance and maintenance. Because customers are paid for kilowatt hours produced over the life of the system, they have an incentive to perform maintenance and replace failed inverters or other failed components. No such incentive exists for the owner of a Buydown-subsidized investment allowance. Rate-based reimbursement creates critical new economic incentives to keep the systems running efficiently, because only metered electrical output is paid for. Consequently, PBI programs protect the utility rate base against the impacts of non-performing systems.

C. PBI Downside: High Tariffs

One of the largest risks of paying for photovoltaics on a kwh-rate basis is that this rate could be inordinately high and exaggerate the true cost. PV systems are typically installed in very small increments of just a few kilowatts. By contrast, even small commercial gas fired peaker plants are thousands of times larger. While photovoltaics is less sensitive to scale than gas plants, scale does matter. (For many years now photovoltaics has been considered competitive with small diesel generators.)[1] In addition, most conventional power plants are paid for over the life of the plant, while PV is either paid upfront or over a period much less than its full life. A hybrid program in the US tried to help customers recoup all the costs of a long-term investment in as short a time as possible. They compressed performance payments (that were only part of the subsidy) into a single year, which resulted in rates of a dollar per kilowatt hour. This accelerated payment highly inflated the real cost of solar electricity.

Another factor that exaggerates cost is when PV is installed in locations that are far from optimal for efficient operation, rather like putting a hydroelectric plant next to a small pond. The German feed-in tariff, for all its virtues, suffers from too many small scale plants, a payment period less than the life of PV systems, and being in a country with rather a modest solar resource. The result is that even their low interest loan program is not enough to avoid an exorbitant PV electric rate.

D. The Solution: A Cost-effective PBI Program

An approach to the PBI tariff that drives down the price and increases the output of installed capacity will deliver benefits to SMUD ratepayers. Most of the PBI program goals outlined below are directed toward minimizing the negative impact of the PBI program on SMUD's rate base. Getting more kilowatt hours, reducing the cost of photovoltaic systems, reducing the cost burden of subsidies, improving benefit relative to cost, scale, management of quality, risk and responsibility, reducing the cost of photovoltaic electricity, internalization of value, and optimizing life cycle value will all serve to maximize benefits and minimize costs to SMUD resulting from PBI systems.

E: A SMUD Feed-in Tariff

A straight feed-in tariff would facilitate a larger scale and fuller integration of photovoltaics into SMUD's generation and purchasing portfolios. As a leader in solar photovoltaic development, SMUD has the opportunity to:

- Accelerate the PV development schedule
- Lower average installed cost/watt of PV systems
- Maximize benefits and minimize downside risks to SMUD system costs
- Improve performance and reliability of PV installations in Sacramento

This can be done while attaining SMUD's program goals of:

- Exerting continuously downward influences on price
- Supporting market force objectives
- Attaining an installed cost of $4/W without subsidies

All these objectives point toward SMUD adapting a German-style feed-in tariff rather than a hybrid PBI with an upfront payment component. Any hybrid system will greatly increase initial annual costs, displace available tax benefits, and increase program complexity. An emphasis on developing large commercial systems – and seeking opportunities for integrated, multi-site, third party development – will help bring down tariffs paid by SMUD without diluting participation in the SMUD PBI pilot program. Such consideration underscores *large scale* in *both* the size of PV systems installed *and* in the number of sites per transaction under the tariff.

The SMUD Board's commitment to taking PV to the next level should be reflected in the structure of its PBI program. Targeting high-growth markets first – such as commercial and new residential markets – will help achieve substantial and rapid market penetration. Payments based on performance rather than capacity will adequately reduce risks for SMUD, and this will help justify a needed scaling up of its PV program. Moreover, a move toward integration of program components will enable SMUD to minimize subsidy payments without compromising participation levels. SMUD has the opportunity to deliver the unprecedented market power of the German Feed-in Tariff model and establish system integration by monetizing renewable energy, distribution, transmission, and peak generation benefits.

2. Eleven Goals of a Performance-Based Incentive Program

Several years ago, the biologist and social activist Dana Meadows wrote a little known but important article on how to effectively intervene into systems to make them more productive. She described different approaches, such as adjusting quantities of flow, creating feedback systems, providing information, and setting rules. She ranked these in order of importance, and at the top of the list was— setting the goals of the system. Setting goals is the most powerful intervention technique since it governs the result of all the other system processes. An important dynamic of goals is that they tend to become not only the motive for action, but also the measurements, testing criteria, and the true standards of success.

Goals of performance-based and other incentive programs can be quite varied and depend on the values and perspective of those who create them. In Germany, for example, a principal goal has been to internalize the external values of photovoltaics. These values include: reduced spending for the future cost of fuels, energy security, reduced pollution and global warming, and the electrical grid support provided by distributed generation. Other programs, such as the buy down funds provided by the California, Japan and Australia, seek to cut the cost of photovoltaic systems for customers, stimulate demand, grow manufacturing capacity, and, hopefully reduce the cost of solar energy. PV programs tend to share all these goals, but different programs rank them quite differently.

The success of photovoltaic programs can be measured in different ways, depending both upon the measure used and perspective from which it is viewed. Measures of success can include the following: popularity of a program, installed kilowatts of capacity, lower product costs or higher efficiency. It is also important to understand how the program is viewed by the different stakeholders who often have quite different values. Rebates directly and immediately cut the cost of photovoltaic systems for the individual customers. Manufacturing costs are affected by the rebate only indirectly, and frequently over a longer term. Rebate program funders, however, perceive rebates as a cost. These different interests often have to negotiate and compromise to get an acceptable program funded and administered in workable way.

In all cases the foundation and measure of success is laid by the generally accepted overarching goal or purpose. For photovoltaic system programs these can be surprisingly varied, and are intimately tied to the type of program adopted.

1: Producing More PV Kilowatt Hours

The most fundamental reason for creating a performance-based incentive (PBI) is to get people to produce more electricity from their photovoltaic systems. Current upfront rebate payments are designed to reduce the purchase cost of photovoltaic systems. As such, they essentially pay people to spend money in the same way that “50 PERCENT OFF!” sales encourage consumption. But paying for capacity is not the same as paying for performance or output.

Upfront rebates offer a customer who puts up cheap solar modules half buried behind shade trees the same rebate as one who puts the best modules in unobstructed sun.

SMUD records show that performance of systems installed under its rebate programs can vary by more than a factor of two (800 to over 1600 kwh/kw/year). Differences arise due to shading from trees and other obstructions, orientation of the modules, choices of equipment and its quality, installation, and operation and maintenance practices. The weakest form of quality control, e.g., a simple minimum standard of 1400 kWh of annual production from each installed kilowatt, could improve the "fleet performance" by 5 to 10 percent. A better program, which adds a reward for performance, could achieve even more.

If maximizing the improvement in annual kwh/kw production over existing SMUD PV system performance is the primary goal of the SMUD PBI program, then the target market should probably be the residential retrofit market sector since that market almost certainly currently has the most inefficient performing PV systems. However, if maximizing the annual kwh/kw production of new PV systems is the goal, then the large commercial and industrial market sectors should be targeted.

2: Reducing the Installed Cost of Photovoltaic Systems

Another closely related goal of all rebate programs is to reduce the installed cost of photovoltaic systems. Since high cost makes solar energy "the elephant in the living room" that no one wants to talk about, strong efforts have been made to bring costs more into line with other ways of generating electricity. The principal tool has been to generate demand so that PV module manufacturing costs can decrease with increasing economies of scale of production. Globally, this has been somewhat successful. In California, average costs for photovoltaic systems installed under the Energy Commission's buy down program have decreased about 20 percent since its inception. Accounting for inflation this represents a decrease of 35 percent in terms of real or "fixed" dollars. Of course, rising global demand is the real reason for this effect and not just California's programs. Nevertheless, California's PV demand has contributed significantly, as well as encouraged (and informed) the efforts of others by its example.

Design and installation efficiency improvements have also contributed to reducing installed costs. Examples of these improvements include: modular system design and installation, prepackaged PV systems, and non- roof penetration ballasted installations.

More than one rebate or incentive program tool can be used to reduce cost; each leads to different results over the long and short term. For example, a program that favors large-scale installations or coordinates volume purchases can have an immediate impact on cost. (Goal 5)

If reducing $/kw installed is the primary goal of the SMUD PBI program, then the large commercial and industrial sectors should probably be the target market. They can best take advantage of the economies of scale for product purchases, design, installation, operation and maintenance, while benefiting from tax incentives not available to residential customers.

3: Reducing the Cost Burden of PV Subsidies

Some people in the photovoltaic industry bemoan the fact that they are supported by subsidies and feel a moral and a financial responsibility to "get off the dole." (In some respects this is quite ironic as almost every form of energy generation is supported with more government funding than photovoltaics.) Subsidy programs are set up to decrease over time with the idea that this reflects the rate at which the industry can lower costs. Another way to decrease the burden of subsidies is to distribute payments over time.

One way of structuring a PBI is to make monthly payments for electricity produced over part or all of the life of a photovoltaic system. Net metering is in essence a baseline PBI that "pays" or values PV production that displaces utility energy over the full life of the system at the same rate as delivered electricity. A premium over this amount can be equated to the value of an upfront capacity rebate, only the payment is made at a per kilowatt-hour rate. While this directly ties the rebate payment to the PV electricity production, it also stretches the payment over time.

A PBI, if it is set up over a long time period of 15 or more years, can achieve the goal of lower cost by a different means. A major reason why photovoltaics is such a good idea for our future is tied to the fact that other ways of generating electricity are, for a variety of reasons, becoming more expensive. The dramatic increase of higher natural gas prices on the SMUD 2005 commodity budget is evidence enough of this. Inflation, the increased cost of finding and delivering fuels, and improved safety and environmental regulations are all factors.

Credit-based (or more accurately: debt-based) money has become the global standard since the Great Depression and almost all prices have increased with its rising tide. A principal exception has been electronics, particularly semiconductors, of which photovoltaics is an example. This technology has the extraordinary capacity for miniaturization, and the continuous reduction of energy, time and material. Production on a vast scale, and in areas of the world with low labor costs, has reduced prices further.

Once a PV system is installed its lifetime electric cost is essentially fixed (except for O&M costs and inverter replacement costs, which are relatively minor), whereas the price of other sources of electricity is not. Inflation rates in the energy sector have run about 3 percent annually recently, but even a 1 percent annual rate compounds its effect over time. SMUD's 2005 Budget Document reflects a commodity cost increase of $87.4 million or 20% above the 2004 budget, largely attributable to the recent, sharp increase in the price of natural gas. Inflating energy costs, even without decreasing photovoltaic prices, will eventually make obsolete a PBI with a premium over existing electric rates. This fact can be used to advantage if a long enough time frame is considered.

If maximizing kilowatts/$ of incentive payment or kilowatt-hours/$ of incentive payment is the primary goal of the SMUD PBI, then a program that provides for a low interest loan coupled with a long term PBI payment directed at the large commercial and industrial market sectors should be considered.

4: Improving PV Benefits Relative to Costs

Improving "benefit/cost ratios" can be done in several ways. Annual output of systems can be increased, (as in Goal 1). But the same result can be accomplished by increasing the longevity (Goal 9) or reliability of PV systems (Goal 6), by making sure repairs and maintenance are properly performed, and the system is kept in good working order. Decreasing the system cost while maintaining output will also achieve the same goal, as will any combination of these. Improving benefit/cost is thus one of the most flexible goals, which can inspire a variety of creative efforts.

While improving the cost-benefit ratio could mean lowering the cost of solar electricity per kilowatt hour (Goal 7), it could also mean enhancing the value attributed to the PV electricity produced (Goal 8).

This goal could be most easily achieved with a PBI program targeted at the large commercial and industrial market sectors.

5: Scaling of PV Projects and Programs

Making the scale or size of a photovoltaic program into a goal is the ultimate "marketing" perspective and can realize several important benefits. One is the rapid contribution to achieving renewable portfolio standards, with its attendant improvement in environmental impact. Another is significant savings on the cost of photovoltaic systems (Goal 2). In our interviews with people in the photovoltaic manufacturing industry, a threshold has been identified in the range of 30 to 50 total megawatts purchased over a 5 to 10 year period, where significant savings can be realized. SMUD's current purchase levels, in the range of a megawatt per year is way below this threshold level and thus is not able to take advantage of economy of scale. It would require purchases closer to the range of 3 to 5 megawatts per year to provide the kind of guarantee that would financially support a significant share of a factory's output. The exact savings depend on the components, types of installations, portfolio of PV systems, and market conditions. If these are favorable, then one could expect to lower installed cost as much as 10 percent for equivalent systems. Under the currently constrained supply of PV modules, the savings would likely be less.

As most photovoltaic programs have a budget that is not particularly elastic, payments must be made out of a given annual budget. If, for example, a program pays out over a ten-year period a PBI for each PV system equal in total to what would have been paid upfront, then only one tenth the amount is paid in each year. While the same total amount of photovoltaic installations will be funded over the ten-year period, the rebate will only pay for one tenth of the systems in each year. The ten-year performance based payments could potentially pay for all these photovoltaic systems to be constructed right from the start and fund them simultaneously. The result is that the PBI can accelerate a program so that more PV capacity can be funded in each year. This can be used to leverage construction at a rate where significant economies of large scale purchase can be realized.

Another dimension of scale is on the micro-economic level of the individual customer or photovoltaic system. Considerable economy can be gained by building large photovoltaic systems. Larger PV systems result in reduced gross system cost per kilowatt of capacity installed, and also a reduced cost of the PV electricity produced.

Achieving this goal of larger scale projects and a larger scale PV program would, like other goals listed here, also involve targeting the large commercial and industrial sectors and the public sector.

6: Managing Quality, Risk and Responsibility

The photovoltaic industry has come a long way in the improvement of the quality of their products. In addition, warranties up to 25 years on the performance of the modules go a long way toward mitigating risks. Extended warranties on inverters and mounting equipment means that most of the replacement cost and equipment reliability risk is assumed by manufacturers as part of the up-front cost paid by the customer at the time of equipment purchase.

There is also the question of performance, which has more to do with choices made by purchasers and installers (Goal 1). These choices can be influenced by incentive programs, which have typically made the performance of PV to be somebody else's problem. While program administrators do not have to take direct responsibility for performance, controls, incentives and program design can improve quality and performance while reducing and managing risk.

The main shortcoming of residential and business customers taking responsibility for their own photovoltaic systems is that frequently they do not know what to look for or how to address a problem if it arises. In addition, many people simply do not want to be bothered. For this reason it is better if the electric utility monitors the performance of the PV systems, sets the standards for performance, and creates incentives for improving practice.

Few investments are more important to this effort than maintaining the inverter and replacing it when it fails, which is typically far short of the life span of the solar modules. This relatively simple task will increase system life 50 to 200 percent, as inverters last 10 to 20 years, while solar modules should continue to produce electricity for at least 30 years.

While the inverter is the most likely component to fail, other issues can affect performance and value, such as soiling, growth of shade trees, or changing conditions of the property.

If this is the primary goal of a SMUD PBI program, then the large commercial, industrial, and public sector market sectors should be targeted since monitoring, extended warranty, and replacement costs can be minimized for larger systems as a percentage of total system costs.

7: Reducing the Cost of Photovoltaic Electricity
Reducing the cost of photovoltaic electricity is a little like grabbing a partially filled water balloon. The cost of solar electricity can drop if the cost of equipment declines (Goal 2), but only if output is comparable or better. Longevity (Goal 9) is also critical, as a system that lasts 30 years produces more electricity than one that lasts only 20. On the other hand, time takes its toll on PV systems, and on some PV technologies more than others: amorphous thin film modules tend to age faster than high quality single or poly crystalline modules.

Ownership and scale of purchase is also significant. Commercial solar electricity costs are typically lower than residential costs, because of their larger scale, which provide installed cost reductions of 20 to 30 percent (Goal 5), and because of large tax benefits (up to 45 percent on the remaining cost) that are not available to residential customers. These combined effects mean that many businesses will pay less than half of what a residential customer pays for solar electricity. And this is without the benefit of rebates or incentives.

An interest free loan program, combined with incentive payments could help to minimize the difference between the cost of PV power and current electric retail rates. In effect, if these elements are combined in the right way, a business can be given a rate freeze on the solar portion of their electricity. As rates increase over time, either the performance incentive can be phased out, or the business customer makes a profit.

If reducing the cost of PV electricity is one of the primary goals of the SMUD PBI program, then the large commercial and industrial market sectors should again probably be the primary target market sector.

8: Maximizing PV Production Coincident with SMUD System Load Profile
SMUD's system load profile peaks around 6 pm in the summer. This is when the generation, transmission, and distribution systems are most heavily stressed from a reliability viewpoint and the time when system costs are the highest. To the extent that the distributed PV generation profile can be shifted to more closely match the SMUD system load profile, then PV systems will provide added system benefits in the form of reduced peak energy costs, capacity credits for peak generation reliability, credits for deferral of transmission and distribution upgrades, and other system benefits. Fixed tilt PV systems oriented south have a summer PV output profile that provides between 80-85% of their nominal rated power for the 5 hours in the middle of the solar day. Single axis trackers provide 80-90% of their nominal rated power for 10 hours during the day. Fixed tilt PV systems oriented to the west provide a better coincidence of the PV production profile with the SMUD system load profile. The further westerly the PV orientation, the better the coincidence of the two profiles. One study done for SMUD shows that the capacity credit can be increased by 25% for an orientation 30 degrees west of south while only suffering a 0.2% decrease in annual capacity factor. On the other hand, a complete westerly orientation may provide a 48% increase in capacity credit with only a 2.5% decrease in annual capacity factor. A PV rate schedule could be developed that would be rate neutral but would place a higher value on

PV generation that is closer to the system load peak than PV generation that is away from the system load peak.

If this is a goal of the SMUD PBI program, this would apply to all market sectors. However the large commercial and industrial market sectors have more flexibility of implementing a westerly PV orientation on large flat roofs, and it would be easier for them to implement.

9. Internalizing the Value of PV Energy

One approach to the economics of solar energy is to treat it in terms of its premium value. Net metering is a basic case example of this principle. If solar modules are installed at a central utility generation site, then they are competing with much cheaper energy sources, such as gas, nuclear hydroelectric and coal power plants, which can cost 5 cents a kilowatt hour or less. These other sources of power have a major disadvantage relative to photovoltaics: they cannot be placed on a roof or ground mounted on a customer's property. As a result the power they generate must be sent through transmission wires over long distances and then distributed to every last house, school, business, park, church, garage and work shed. This system is expensive and adds considerable cost to the transmission and distribution of central station power systems. The result is that electric power is worth more at the site of delivery than at the generation site. Net metering internalizes these costs by making PV power produced on-site equal in value to the retail rate of delivered power.

But there is considerably more value to PV systems than is expressed in the delivered price of electricity. There are significant environmental benefits to PV power. Estimates by the US EPA suggest that air pollution alone costs the nation about $100 billion a year in lost work and damage to health and infrastructure. Air pollution from generation of fossil fuel electricity is a significant contributor to this cost. In addition, the impacts of climate change are likely to exceed the cost of air pollution, with potentially devastating impacts globally. There are also specific benefits photovoltaic systems provide to the electrical system such as: insurance against loss of fuel supply; relative immunity to wide spread grid failures; protection against natural catastrophe or terrorist attack; protection from rate shock; and delay of fossil fuel depletion. The additional benefits of distributed generation are also important. The California Energy Commission has stated that renewable generation essentially helped the state weather some of the worst events of the energy crisis of 2000–2001.

If utilities valued these benefits with even approximations of their real value, photovoltaic electricity could be purchased at rates comparable to other premium sources that supply marginal amounts of the total electric power (e.g., peaking power). PV would then be valued in the same way transformers, wires or electric meters are valued, which don't even produce any electric power but are an essential part of the electric system. In fact, such an approach is normal in the marketplace and is the reason why people pay more for a meal cooked and served at a restaurant than for unprepared food at the grocery store. The added value is generally recognized and readily paid for. Internalizing the value of photovoltaics requires some education and finding those who will value it and develop valuation methodologies that can be easily applied on a system specific basis.

Establishing the full value of PV power and incorporating it into any PBI price is common to all market sectors to be targeted by the SMUD PBI program.

10: Optimizing Life Cycle Value

Some values are only realized by "stepping back" and reexamining assumptions and frequently ignored aspects of performance. For photovoltaics these values include the very reasons why photovoltaics are installed in the first place. There is the assumption that this form of electricity generation will "save fossil fuels", protect the environment, perform reliably and continue to produce for a certain length of time. But these benefits of PV are not usually evaluated (as described above) or included in life cycle cost analyses of PV. There are wide differences in technologies in manufacturing solar modules, and these have different costs to the environment and in the energy or fuel used to produce them.

The amount of energy used to produce solar modules is often measured in "energy payback time", which has decreased significantly over the years. The most energy intensive element is manufacturing silicon ingots, and much of this is wasted in the process of cutting the ingot into wafers. Payback on high quality modules can take a number of years. In the early 1990s a European study found that modules made with polycrystalline cells take about 7 years to get the energy back. Adding in the energy for transportation, installation and other components would likely add up to a few more years worth of energy payback. Assuming a life span of 30 years, the energy payback would be about 3 to 1. Amorphous silicon technology uses about 1/10 the energy to produce the cells, and has payback periods of less than a year. Other processes, such as those developed by Evergreen Solar, Astropower (now GE Energy), Solaicx, Sliver Solar and Spheral Solar produce high quality cells with much less energy usage. It should be noted however that the fossil fuel generation industry does not consider this issue in their cost analyses.

Another factor is the longevity of the PV system. For many years the assumption was that PV modules only could be assumed to last for 20 years, with warranty lives shorter than that. New warranties which extend 20 to 25 years have helped greatly to break through this barrier, and now 30 years is a more common useful life assumption. However, researchers and some in the industry believe that high quality solar cells will last much longer than this; some say up to 80 years. The silicon crystal itself does not degrade, and aging is attributed mainly to the plastic encapsulate and the electrical contacts to the silicon substrate. Very different assumptions would have to be made about cost, value and energy payback if the life span of a photovoltaic system is much longer than 30 years. And certain PV technologies are much more likely to outperform current expectations than others.

Another aspect is the end of the life cycle of solar modules and other components. This includes whether there are toxic materials such as cadmium, arsenic or lead used in manufacturing the PV modules that are purchased and how to dispose of or recycle them.

11: Gaining Knowledge and Experience
Photovoltaic technology and its implementation are still being explored, and there is much to be learned. Development of new technologies and practical ways to implement them will certainly be the path toward increasing performance and decreasing cost. Gathering of data and learning from experience are among the best ways to bring about improvement.

Conclusion.
Goals are easy to overlook because they are often taken for granted. But they are the most essential element of a photovoltaic program, since they determine not only the purpose, but also the measure of success. They also help to form and connect the subsidiary program elements. Identifying goals will allow for designing a program that has the highest value to SMUD and highest chance of success. Before a SMUD PBI pilot program can be effectively designed, SMUD needs to identify and prioritize the goals that it is seeking to achieve in the program.

3. A Typology of Performance Based Incentives

In the US the term "Performance Based Incentive" has come to be identified with a fixed rate per kilowatt-hour (kWh) at which renewable generation systems are purchased by customer or private generator companies, and then reimbursed by a utility or the government at a fixed rate. International convention calls a direct payment rate a "feed-in tariff". The recent German national feed-in tariffs pay several times the value of delivered power. An example of a performance incentive that is *matched or equal to* the delivered price of electricity is "net metering" , which replaces utility supplied power with on-site photovoltaic electricity, and runs the electric meter in reverse when excess power is generated.

Lower payments than the market rate for delivered power have also been established in a number of places, which tend to discourage the use of PV. A notorious case is the Solar One residential development project in Phoenix. [2] The regional utility agreed with a real estate developer to net meter the project. But, after the developer sold the PV system to residents the utility abruptly changed policy and started buying back solar electricity from the customers as wholesale purchases of 2.2 to 2.4 cents a kilowatt hour during peak billing periods. During these same hours they were selling electricity to the customers at 9 cents a kilowatt hour. Residents were producing as much electricity as they consumed and yet in some cases ended up owing significant bills to the utility. This is an object lesson on how inadequate payments can ruin what started out as a very good solar program.

Another type of performance incentive is a tax credit given on a per kWh basis. Such payments are significantly less than the cost of generation. The wind industry in the US has benefited from these for at least the last decade. This has been credited by some analysts with overcoming the worst problems with the earlier huge write-offs for installing wind turbines without regard to performance. The new 2004 tax bill includes for the first time a kWh photovoltaic tax credits. Though the reimbursement rate is absurdly low, and anti-double-dipping rules preclude use of this incentive with other tax benefits, this is a significant shift in national policy.

There are also so-called "hybrid payments", in which an upfront rebate for the purchase price of a PV system is followed by performance payments. Part of a performance payment can also be assigned to the contractor, so they have an incentive to install systems properly. This addresses a paradox of incentive programs that reward the buyer, while the installer, who is typically in the best position to affect performance, receives no direct benefit for performance.

Up front rebates can are used as leverage for increasing performance through performance standards. These can be as basic as requiring proven equipment and good warranties. They can also tie payments to the tested performance of components or minimum expected output levels. The reason these are performance incentives is because they directly affect eligibility for and level of payments. In our view, standards are an essential component of a successful program.

4. Elements of PBI Programs

A. PBI Structure

There are three types of payment systems set forth here which we will designate: Feed-in Tariffs, Premium Value Payments, and Hybrid Subsidy Payments. Each of these will be defined and described in this section.

The Feed-in Tariff (FiT) involves paying the full cost of photovoltaic electricity in the same way power purchasers pay the full cost of any other source of electricity. Feed-in tariffs are not normally designed to generate a profit, but do cover interest on a loan and other assumed expenses. The tariff rate represents an actual purchase by the utility from owners of PV systems, and the extra cost to the utility for paying out the tariff is recovered by a surcharge on customers' bills. The theory is that the cost of PV should be borne by all customers for two reasons. First, the distribution of cost reduces the burden on each rate payer to a very small level. And second, benefits of PV accrue to everyone in the form of reduced pollution and energy security. Thus, in the final analysis, all customers are making a purchase of the PV electricity along with its associated benefits.

German payments for small PV systems are equivalent to 75.2 cents/kWh in US currency[3] paid out over a 20 year period. Thomas Starrs has also pointed out that PBI rates in California should be significantly less, due to the higher solar resource in California.[4] We estimate payments structured in a similar way in SMUD's territory, but without any special loan program, would have to be 35 to 40 cents/kWh. The difference is largely due to the significantly higher amount of sun in Sacramento than in Germany. The high payment rates have an excellent incentive effect on customers, if the support they provide for long-term cash flow is coupled to a loan program, as in Germany and other European countries.

Premium Value Payments (PVPs) are not power purchases, but are designed to cover the extra cost incurred by the customer for the PV system. They are paid on a kilowatt-hour basis over a period of years, in the same way as a Feed-in Tariff, only the PVP covers the difference between the normal price of delivered electricity and the higher cost of PV electricity.

The result is a significantly smaller payment by the utility, which does not have to buy the power at retail-plus rates. The PVP benefits from savings at several levels. Any tax credits are subtracted from the system cost, as in the Feed-in Tariff, but since the power belongs to the customer it is exempt from local sales taxes on electricity. This tax is worth about ¼ cent/kWh in Sacramento County and about ¾ cent/kWh in the city of Sacramento. If the PVP is structured properly, there is a good chance that it will not be encumbered by taxes, especially if it is offset by long term expenses, such as interest payments or O&M.

While PVPs are not power purchases as such, this does not exclude having the utility receive some value benefit. New laws in California allow for Green Tag trading, which provides a utility the rights to claim electricity generated by a third party as part of a renewable portfolio. SMUD's

Board of Directors has committed to a 20% renewable portfolio standard (RPS)), which means that customers will own renewable power for which SMUD could offer competitive green-tag payments as a supplement to its current solar rebate program. A PBI delivered in the form of a Premium Value Payment could allow the benefits of photovoltaics to accrue to the SMUD portfolio, unlike the current residential PV installations which are not precisely metered (see the following discussion on metering).

The design of the California Energy Commission's Performance-Based Incentive is not a Feed-in Tariff power purchase of the European type, but a PVP.

Hybrid Subsidy Payments (HSPs) involve an upfront payment combined with a payment or series of payments made at a later date based on kilowatt-hours generated. The payment term is typically short: from 1 to 3 years, and the performance rates can be quite high, up to a dollar/kWh. This type of program is designed to avoid a radical shift of marketing strategy or customer awareness. HSPs avoid the main pitfalls of long-term PBIs, which is the challenge of dealing with high up-front costs for PV and the decreased value of future payments (the problem of net present value). There are several significant drawbacks though: the programs can be quite complex to understand and administer, and PV is still marginalized from decisions relating to generation and renewable portfolio evaluation.

We expect that a hybrid subsidy payment works best for residential systems from an economic point of view, since residential customers' tax considerations are limited to interest on mortgages. For a business that can take a tax write off on the principal, the rebate displaces significant tax savings, and thus shares this disadvantage with other PV rebate programs for businesses. Because businesses can write off up to (approximately) 45 percent of the purchase price after the rebate is subtracted, the incremental benefit of the upfront rebate is only 55 cents on the dollar.

Other PBI structures. While there are a number of types of policies that reward or pay for the output of photovoltaic systems, not all are equally likely to be considered by SMUD for implementation. For example, SMUD could offer tax credits for kilowatt-hours as the US government currently does, but it would have to exercise its power to tax in order to give the credits. A second option would be using the Federal production tax credits that have just been implemented, though we expect that the narrow time window during which it is available would make it difficult to realize for large new PV projects unless it is renewed in 2006. It is our understanding that this benefit excludes other special federal tax benefits such as the 10% energy tax credit. Any use of the 2 cent/kWh renewable energy tax credit would have to be weighed against the loss of other tax benefits. SMUD could also provide a payback system for photovoltaics at a rate lower than net metering as a number of utilities have done in the past under PURPA regulations, and under national German law in the 1990s.[5] While all of these are possible, we do not recommend them at present as we believe that they would put unreasonable constraints upon the PV program.

B. Fund Allocation
A crucial topic raised in the context of discussions with industry experts was who gets paid and who pays for the incentive. This depends upon the program structure and choice of program elements.

A power purchase, such as a feed-in tariff, would have to be implemented by SMUD. The structure of the PV program does not seem to be currently set up for this kind of arrangement. It would require the SMUD department responsible for power purchases and generation to be intimately involved, which we see as potentially quite desirable *if* that department could be persuaded of the value of this approach. Such a decision would also likely have larger budget implications that might require a definite, though likely rather small, rate increase. The high tariffs in Germany have been accomplished with only an estimated 1 percent rate impact. If this were phased in over a few years it would likely be unnoticed. Or alternately, it might be embraced all at once by the board and the customers if a significant scale of PV implementation (and its benefits) could be demonstrated for this relatively small cost.

The Premium Value Payments as well as the Hybrid Subsidy Payments are more suited to being paid out of SMUD's current PV subsidy program. The amount of incentive money involved would be far less and could be tailored to fit into the current (and future expected) subsidy budget. Since these would not be power purchases as such, other departments would be less involved financially. There is still the potential that the budget for power purchasing might be tapped as a supplement to pay customers for the equivalent of a local Green Tag program. The value to the customer would then be built upon the cost of delivered power. To this would be added the future expected increases in electricity rates, against which the PV system would serve as a hedge.

The payments listed above are essentially reimbursements for those who would actually be buying the PV systems. The purchasers could be customers, a third party developer, or SMUD.

C. Payment Amounts
We have seen above how the program structure directly affects the amount of payment that must be paid by SMUD. The commitment to cover the full cost of photovoltaics is integral to any program, but the payment level for the developer or the customer is also dependent on the scale of the PV project. Small PV systems retrofitted on existing roofs are the most expensive, while large commercial systems could easily cost half as much (or less) once tax benefits are included.

A Premium Value Payment on the other hand, is much cheaper, especially if it is paid out over a long enough term (see Section D. Term). For commercial customers who can take large tax deductions (up to 45 percent, including federal and state depreciation plus 10% federal tax credit), the premium can be as little as 20 cents/kWh if paid over a 15 year period. It is also important to understand that a PVP has much higher sensitivity to factors affecting cost (such as interest rates and term) than a feed-in tariff.

D. Term
A full feed-in tariff for the residential sector could cost in the range of 90 cents to $1/kWh if the full 30 year cost of the PV systems is to be paid over a 15 year period. This would drop to below 40 cents/kWh if paid over a 30 year term. This illustrates the dramatic effect of term on a PBI program. Of course, one could account for the value of electricity beyond 15 years in the calculation and derive a smaller payment. Additionally, it should be recognized that residential customers are not always looking to payback as the ultimate criteria.

In addition to the term of the PBI payment, there is also the question of the term of a loan. An important question is whether the term of a PBI payment should be equal to the length of a loan. This becomes quite important when considering cash flow, which is greatly helped by matching the two.

The third term element is the expected life of a PV system. In the past this was generally assumed to be 20 years. In retrospect, this was a rather timid assumption, while today it is unreasonably short. With performance warranties on modules running 25 years, it is conservative to expect a PV system to last 30 years. Industry light cycle flash testing has shown reasonable performance for an equivalent of 120 years. The limiting factors are thus whether the inverter and other parts are repaired or replaced, and the eventual need to re-roof or remove the modules to another location. Ongoing monitoring and utility involvement can resolve these limitations to a great degree, providing the assurance of O&M contracts for the PBI program, and having a venue for appropriately redeploying, reselling or reinstalling modules if they need to be moved.

E. Loan/Financing

> Net income will be reinvested in the business and allow us to fund ongoing capital improvements without borrowing, another key to building equity.
>
> *~2004 SMUD General Managers Letter, p2.*

The largest market barrier to photovoltaics is its high upfront cost. This places PV at a significant competitive disadvantage in relation to gas power generation, where the majority of expenses are incurred over the life of the gas plant, principally in the form of fuel costs. The upfront rebate addresses this problem by reducing the cost to the customer by 30 to 50 percent. A utility that makes the transition to a PBI program must recognize the loss of this key market benefit for the customer/purchaser of a PV system.

As it is unlikely that many customers would either have, or be willing to pay, the full cash up front for PV systems, a loan component should be considered essential to a PBI program.[6] Loan programs have been essential to the market success of the German program. The introduction of zero and low interest loans have helped the market to grow at explosive rates. There was not more than 70 megawatts total PV installed in Germany during the entire 1990s when no loan component was available, even though very high payment rates were given in nineteen of Germany's largest cities. Since the low/zero interest loan programs were created, feed-in tariff rates were *reduced* significantly, yet the total PV installed has soared 10-fold to over 700 Mw in 2004. This is much larger than the amount of PV installed in the US over the last 50 years.[7]

Financing could come from one of three likely sources: banks, investors, or SMUD. If customers go to a commercial bank, then they will have to pay going interest rates. A credit union in Southern California has recently announced a special "No Hassle Solar Loan" program (complete with PV modules on the bank's roof), with rates as low as 4.25 percent for customers with optimal credit.[8] Commercial loan rates, however, can be much higher. Many people include PV systems in a home loan which allows for a tax write off on the interest, lowering the effective interest rate by up to ¼, depending on the tax bracket. Alternatively, a third party investor is likely to want a higher rate of return than this.

An excellent option for SMUD would be to use its access to muni tax free funds as a lending source for customers to purchase PV. We assume that rates not higher than 4 to 4.5 percent could be easily obtained by SMUD if they had to borrow the funds on the open market. Alternatively, the funds could come in whole or in part from an internal loan fund out of SMUD cash (or equivalent) assets. The following scenario is an example of how a SMUD-funded loan program could work.

> **SMUD Equity Account Scenario:** Assume ten megawatts of PV installed on large commercial rooftops requires about $75 million in borrowed funds to finance. This could be loaned out over a 15 year period to SMUD customer/owners. The initial money is borrowed from the open market at 4 percent. Over a period of years SMUD implements its strategic directive to increase available cash assets. This money displaces the money borrowed by SMUD at interest with internal cash unencumbered by interest obligations. The benefit can be passed on to the customer in the form of lower interest and SMUD can lower the PBI rate to reflect this lower cost. The result: the financed cost of PV systems will drop, and lower PBI payment per kwh will result, and more PV systems can be supported on the same PV program budget.

Another option would be to build up the cash account quite quickly, though this might require a modest rate increase. The result would be that it would now be possible to lend the money out at very low or even zero interest. This type of loan has been (and is) an essential part of the German and Dutch PV programs. Based on preliminary spreadsheet modeling we have done, a zero interest loan could bring PV electric rates for large commercial customers (after tax benefits) close to long term retail electric rates, with a 30 year average difference (assuming 1% annual escalation for electric rates) perhaps as little as 3 to 4 cents/kWh. A 40 year production life reduces the difference between PV costs and SMUD utility rates to near zero based on these assumptions (i.e.: 45% tax writeoff and 1% annual SMUD electric rate escalation from 2006 levels.)

Lengthening the term will increase the accumulated interest. Here is the effect of loan term on a $100,000 loan at a 4.5% compounded interest rate, and assuming a 133 kw PV system at an installed cost of $7.50/watt (this makes the principal $1 million):

Loan Term:	10	15	30
Principal	$1,000,000	$1,000,000	$1,000,000
Accumulated Interest @ 4.5% annual rate	$243,660	$376,987	$824,066
Total	$1,243,660	$1,376,987	$1,824,066
Monthly Payment	$10,364	$7,650	$5,067
Initial cost per watt	$7.50	$7.50	$7.50
Added interest cost per watt	$1.83	$2.83	$6.18
Total principal plus interest per watt	$9.33	$10.33	$13.68

Though lengthening the term will definitely reduce the monthly payment, it will also skyrocket the total cost. (Interest on the 30 year loan adds 82 percent on top of the principal.) On the other hand, this effect can be greatly mitigated by lowering loan rates. Since the PBI is structured to cover the balance of costs above retail electric rates, offering the best possible loan terms is even more in SMUD's interest than the customers.

A very important consideration for any loan program is Net Present Value (NPV) which is the assumed cost, or decreasing value, of money received (or paid) farther and farther out into the future. Since a dollar five years from now is considered to be worth less than a dollar today, a PBI payment given out over time suffers from this NPV loss. The NPV is calculated at a rate of interest, which is the assumed rate at which future money loses its value (this typically is the borrower's discount rate reflecting the borrower's time value of money). Since interest creates the decrease in value for future payments, a decrease in interest will reduce this loss. At zero interest the loss approaches zero, though inflation could be argued to be a baseline charge for money that decreases the NPV of future payments. If the PBI is structured as a hedge against inflation, and if the interest is low or zero, then the NPV penalty of a payment over time could be minimized or nearly eliminated. These considerations become quite important when comparing a PBI to a rebate paid upfront.

Case Study: Indian Solar Loans - Interest Rate Buy-Down

An example of using a subsidy to offset or reduce the interest rates offered through a commercial bank is a partnership between two Indian banking groups, Canara Bank and Syndicate Bank, who have developed two loan programs for solar home systems (SHS). These programs use UN and Shell Foundation Resources to buy down the initial financing costs of lending to the residential sector, whose customers have no capital whatever.

Providing an interest rate buy-down allows Indian partner banks to offer loans to customers at concessional rates of interest, initially 7% below their prime lending rate, currently hovering around 12%. A corpus of USD 0.9 million will fund interest subsidies for loans to buy approximately 18,000 solar home systems. These subsidies will phase out over time.

The loans are accessible to customers of established solar rural electrification companies, in this case targeting thousand of homes and small businesses. The interest rate buy-down has been used previously in the Indian sustainable energy sector, particularly with solar water heating systems, although the concept has only just recently been attempted for solar PV financing by one vendor on a small scale. We feel that such an incentive can address a number of barriers without unduly distorting the market. It should be noted that the incentive will be a small share of the total financing with the banks putting up most of the capital.

In terms of risk sharing, the banks will carry 100% of the exposure and therefore should be motivated to maintain quality loan portfolios. Price distortion should also less of an issue since the rebates would be subsidizing the financing cost, not the capital cost.

Various market incentives were considered during the design of this program. Not being familiar with solar PV technologies, bankers aren't very price sensitive to system costs (i.e., they don't have a good feel for what a PV system should normally cost). UNEP providing a capital cost subsidy for SHSs would therefore not have much impact on their motivation to lend for the product. However bankers are enthusiastic about the possibility of offering preferential terms to their customers, and therefore subsidizing the financing cost of a system is a more effective inducement for bank participation than subsidizing the capital cost of a system. A third possibility would be to subsidize the risk of SHS credit portfolios through the provision of partial loan guarantees. However the Canara and Syndicate banks are already willing to carry 100% of the risk exposure, therefore in this case the guarantee form of subsidy isn't needed.

One of the most attractive features of an interest rate subsidy is that it doesn't distort the market, either in terms of the capital cost (i.e., the ticket price) that the customer associates with a PV system, or the risk that a banker associates with a solar loan.

F. Distribution of Risk and Responsibilities

> A key to meeting financial goals is to limit the risk associated with exposure to purchasing electricity and natural gas on the market.
>
> *~ 2004 SMUD General Manager's Letter, p.2.*

In the spectrum of risk in the utility industry, photovoltaics in a sunny region falls far on the low end. The risks of PV, especially if good quality equipment is utilized, are not very great.

Compared to the cost risk of fuels or the safety risks of nuclear power plants, PV is the equivalent of insurance. The cost of PV electricity is not likely to escalate significantly over time, as the vast majority of expenses are fixed upfront. The relatively small performance risks can be easily mitigated, as a large assignment of risk is already borne by manufacturers. Modules are warranted to produce at a minimum of 80% of initial output for 20 to 25 years. There is enough variety of high efficiency modules that this could be made a program requirement.

Extended warranties can be purchased for inverters from manufacturers, which usually come with a 5 year warranty minimum due to CEC requirements. The additional cost on the extension is nominal, and can last 10 to 15 years, depending on the manufacturer. We recommend that such extended warranties be mandatory for participation in a performance based program. This will assure that the inverter will not have to be purchased prior to 10 or 15 years. These two components generally account for 75 percent of the installed PV system cost. Other hardware, such as mounting equipment, wires, connectors, etc., are either so unlikely to fail or so cheap to replace that they do not present a significant risk level.

The main risks for performance of PV systems can be addressed by:

1. Insuring that PV systems are properly sited and designed; this should be done by pre-qualified PV designers and integrators
2. Insuring that proper installation standards are established by SMUD and that there is proper oversight through on-site inspection by building inspectors and structural engineers, as well as SMUD
3. Using qualified installers
4. Buying high quality equipment from reputable sources with sound financial basis and a firm ability and willingness to back up warranties
5. Monitoring the PV systems adequately, which is an integral part of any PBI program; this should be done by SMUD as well as a designated O&M contractor
6. Requiring insurance coverage for PV systems by their owners
7. Allocating part of the PBI program ongoing budget to pay for O&M: i.e., assuring obstructions such as trees or debris are removed, cleaning of modules and inverters as necessary, repairing malfunctioning equipment, etc.
8. Providing a direct access line to SMUD for customers or contractors who might observe problems with PV systems, with SMUD providing the role of a knowledgeable and helpful referee to make sure problems are adequately addressed/resolved by contractors and customers

Other risks to SMUD and lenders should be minimized by:

1. Using sound lending procedures, seriously considering using the services of a bank or credit union to handle large commercial loans

2. Collateralizing the loan with the PV systems
3. Proper legal contracts that protect SMUD from liability

The most significant performance and other risks are actually reduced significantly by a PBI program.

One risk that the current PV Buydown program has is that some customers elect not to continue to have PV on their roof, or a property changes hands and the new owner does not want the PV. An important benefit of a PBI program, especially if it is long term, is that the payments would be discontinued if the PV systems comes down, which limits risks to program funds.

An effective ongoing monitoring program, which should be done by SMUD and the contractor responsible for O&M, substantially removes the second most common risk: that systems are neglected. Inverters may fail or under perform, or a tree limb or other obstruction may shade the modules. Monitoring, combined with prompt attention to repair, should alleviate this problem.

A common performance issue with PV systems is that they are installed in locations with obstructions or with inferior orientation.[9] A relatively minor shading can result in a significant degradation of PV output. [10] A PBI payment system does not in itself assure that PV systems will be properly designed, installed and maintained; however it does provide an incentive for this, and it protects the rebate program from wasting funds on under performing systems. Installers particularly tend to be responsive to the wishes of the customer: they want first of all to sell a PV system. Thus the best way to assure improved performance is through education of customers combined with standards for program participation.

Risks to the customer/owner of PV systems is reduced through program standards and monitoring by SMUD, while a PBI can lessen financial risk by helping loan repayment with an ongoing stream of cash support. In addition, the participation by and leadership of SMUD helps reassure and educate customers.

There has been much timidity in the past regarding the longevity of PV systems, which has tended to exaggerate the perceived risk. Yet, the modules, which typically represent half the installed cost (not counting interest, inverter replacement or O&M), are far more durable than what has been generally acknowledged in the utility industry. In the past a 20 year life span was assumed, but this is hardly justifiable in light of the warranties that now extend to 25 years. The silicon substrate of mono crystalline cells is not known to degrade at all; while the principal parts of the modules that degrade, the electrical contacts and the polymer encapsulant, have been improved over the years. Sharp Solar light-cycle flash tested their top quality modules and found them to generate electricity for the equivalent of over 120 years.[11] They did not test weather, shock or other stresses, but these flash tests demonstrate that the modules, if reasonably cared for, should continue to function effectively beyond their warranty period.

A more serious risk is the variability of PV output. Modules are limited in their power production by the solar resource. This output can vary considerably from day to day and year to year. The result, for a program the pays for kilowatt hours, is that payments in a short term can be quite erratic. Yet, over the course of a year this tends to even out. Data for Sacramento’s solar resource shows that total variation from year to year seldom falls outside of about 10 percent of the average. Apart from the general solar resource is the local availability of sunlight for the modules. Trees can grow, buildings or structural additions can end up shading the modules, and some monitoring, good planning, tree trimming, and even potentially legal protection for solar rights may all need to be in place to reduce this type of risk.

Another concern is the economic risk over a long term payment. The general assumption in our models is that electricity prices are likely to go up. A decrease in electricity prices should not be entirely ruled out, however. Historically, electricity prices have been rising for most of the past century, with only brief reversals when compared to the decades of life for a PV system. A major improvement in global conditions, or significant improvements in technology could effect such a reversal in price trends, as could a global deflation. We note, however, that any catastrophic deflation is likely to be intimately involved with difficulty in obtaining nonrenewable energy, with attendant upward price pressure on fossil fuels.

We suggest sizing PV systems owned by commercial customers so that they supply a percentage of on-site electricity needs that will fall in a range of risk and potential rate impact acceptable to the customer. This way any risk from downward price movements in electricity, the higher price of PV, the potential for loss of tax benefits, and the fluctuating cash flow in paying for the PV system, is adequately hedged by power from other sources. In addition, this limitation has other benefits as well, such as avoiding net metering, a topic discussed later in section 7. PV Value. Residential customers have other requirements, due to their unique load shape, and it does not make much sense to limit the PV system to a hedging size. Important system load and unit cost benefits occur when a residential customer provides as much of their power as possible from the PV system, with a net metering arrangement to support it.

G. Goals, Criteria and Standards

We believe that a program can be tailored to meet SMUD's overall organizational goals as well as specific goals of the PV program. The SMUD installed net cost goal of $4/Watt is reachable in the largest commercial sector if tax benefits are taken into account. Nevertheless, an incentive payment is not by itself enough to assure improved performance. Customers may simply take the payments for whatever kWh are produced, but not necessarily eliminate the lower output performing systems. To assure close to optimal output, this should be made both a goal and a standard for any PV program, as several US PV programs to date have done. The performance range of SMUD's residential PV installations is quite large, ranging from 800 to (apparently) 1600 to 1700 kwh/kw/yr.[12] By requiring a demonstrated minimum system output of 1400 kwh/kw/yr, the SMUD 'fleet average" would likely be improved by 10%, while avoiding wasting SMUD's precious rebate dollars on inefficient systems.

One of SMUD's most critical goals is to accelerate and meet its RPS standard, to which PV could significantly contribute. Maximizing PV installed capacity, along with efficient output from systems, should also be an important goal. A PBI program, because it is paid out over a number of years, has the crucial advantage of allowing more simultaneous construction of PV. A large acceleration of PV installations, the magnitude depending on program design, would be feasible.

It is important to consider criteria other than immediate cost and output. An estimation of the quality of equipment, its longevity and performance are just as important, as are environmental and life cycle issues. A too short-term, narrow outlook opens the door to contractors for using low quality modules to lower bids and win contracts. Criteria must be set up for quality and performance and these need to be explicit so that performance will match expectations.

Goals and standards are not only appropriate for the PV systems and operators, they are also important for the program itself. It is essential that criteria be clearly established and a fair, open process be established for potential contractors. For this reason the refinement of criteria should be spelled out in advance: how PV modules should be mounted, what quality they should be, requirements for inverter and other equipment replacement, moving of PV systems and who pays for it, roofing and reroofing problems, risk and its mitigation, as well as O&M and warranty requirements. The monitoring roles should be clearly defined, with a specific person in each participating entity (i.e., SMUD, contractor, PV system purchaser) taking key responsibility for communication, implementation and monitoring. We recommend using the guidelines we set out in this and future deliverables to make the contracting out process open and fair, as well as to provide a satisfactory outcome for all parties.

H. Metering

Metering is a more complicated issue than first meets the eye. PV output should be independently monitored by state of the art technology, with revenue grade performance meters and real time online records. Such systems are already available and should be required. Metering can be structured to greatly simplify administration, disbursement of funds and O&M.

One important factor in metering is to assure the proper performance and maintenance of PV systems. Several studies have confirmed under performance of PV systems, and one in California showed how under performance can often be fixed quite easily if discovered.[13] SMUD should be the “referee” and check if PV systems are under performing. But it might be beneficial to have an automated data processing system that can flag under-performing systems, or make them easy to identify.

A cross comparison with DOE and SMUD solar monitoring, as well as the performance of other PV systems, and the performance of previously noted SMUD PV systems, should be used to normalize PV output and serve as a standard for comparison so that problems can be quickly identified. Someone inside SMUD should have the designated task to review these data at least once a month, and dispatch O&M personnel from a contracting firm. Any repairs should be checked and some kind of independent auditing would also be desirable from time to time to assure O&M work is done properly and that meters and PV systems are in good shape.

A major metering issue is the contribution of PV electricity to SMUD’s Renewable Portfolio. SMUD’s recorded PV generation in 2003 was reported to be 2,380,000 kWh.[14] Our survey of

135 residential PV systems showed an average output in excess of 1400kwh/kw/year. On this basis the SMUD PV generation represents the output of 1,700 kW of installed PV capacity (peak dc). Estimating an installed capacity of 10,000 kW of PV connected to the SMUD system at that time means it is likely that 8,300 kW of PV generating an estimated 11,620,000 kWh was not counted in SMUD's portfolio. We strongly recommend examination/confirmation of this by SMUD staff as it has very important ramifications for a PBI program. At a delivered electric rate of 9.5 cents/kWh this represents $1,100,000 a year in PV electricity contributing to the SMUD system. Counting this PV by placing revenue grade meters on them would cost far less than the duplicating the purchase of renewable energy by SMUD to fulfill the RPS. Counting PV kilowatt-hours in the future will also assure that it is valued in the right way by all departments in SMUD. We see counting PV output as an important benefit of a PBI program.

Finally, there are economic and program structural questions regarding which side of the customer's electric meter (as opposed to the PV meter) the PV output should be on. Currently the PV output is placed on the customers side, which is a requirement of Net-metering. However, net metering has some key disadvantages. It leads directly to the situation outlined above, that PV power is not counted in its own right but is seen as simply a reduction in demand. Net metering also feeds power backwards into the grid, where it has less value than at the site of delivered power. This has important policy effects that will be explored more in section 7 on the Value of PV.

Placing PV on the customer's side of the electric meter makes sense if the customer is the owner of the system. That way the customer receives the benefit of not having to purchase power back from the utility for a PV system that they own. This has the added benefit that the customer doesn't have to pay the local tax on electricity purchases from SMUD.

Placing the PV system on the utility side of the meter would make sense if SMUD or a third party owned it. The disadvantage would be that the customer would no longer have such a vested interest in the PV system, and as a result would have to be given some extra benefit for its placement on their property. This could include a rental fee or a rate break. Earlier market studies have shown that SMUD customers like to buy PV systems due to the protection of their roofs from weather.

I. Market Sectors

While market sectors are examined in more depth in the next deliverable (1.4), there are some broad points that will be considered here in program design. Other authors have proposed what they conceived to be a logical order for development of PV markets.[15] The principal approach has been to consider the cost of electricity in each sector, and determine in what order the decreasing cost of PV can meet that price. While the general outline for development is descriptively correct for the broadest market trends, we believe that it lacks prescriptive value for a PV program. The approach appears to ignore consideration of the important elements of scale, tax law, financing and the particular qualities of each market sector. The assessment that small scale home installations could bring down costs, for example, only proved true up to a point and was changing by the late 1990s. Assessment of the CEC Buydown program showed that an important PV market transition took place between 1998 and 2002. The reductions in cost were almost exclusively in the commercial sector, and were quite large.[16]

A second problem of the standard PV development models, noted even by their authors, was that significant extensions of the market happened out of sequence. Large PV systems were installed by utilities for grid support and central power generation in the 1980s, long before grid connected home PV systems had penetrated the market. SMUD, while certainly a leader in PV, was not alone in pursuing market trends that did not fit the models perfectly. Statistics measuring PV installed in different market applications have shown for a long time that markets grow side by side, and succeed each other only as a general trend.[17]

A prescription for a PV program must, in our opinion, proceed on a different basis than examining the general market trends or a theory of market succession alone. A PBI program in SMUD's territory can be built up from assumptions that are valid in the SMUD service territory. While the German Feed-in Tariff works well for residential customers, the market mood and program budget may only allow an approach for SMUD that is more economical. The idea of orderly succession should be adapted to financial and program elements appropriate to a PBI program. Customers who can meet the least cost/greatest leveraged benefits should go first, followed by other market sectors as appropriate, and as SMUD's budget for PV allows.

J. Tax Cost and Benefits

Tax policy is an essential factor in reducing the cost of photovoltaics. Commercial systems are already cheaper than residential systems per installed watt by 10% to 20%, and this benefit combined with superior efficiency translates into a lower kwh rate for PV electricity. But the tax benefit enhances this difference to where commercial systems can reduce the cost of solar electricity by more than half that of residential systems. Any business, whether corporate or not, can receive in the first year a 10% investment tax credit. This is further augmented by allowing the 90% remaining balance to be amortized over a 6 to 20 year period, and directly deducted at the corporate tax rate for both federal and state tax. These combine to a maximum deduction near 40% (on the balance). The total benefit is worth up to about 45% of the total installed cost of the PV system.

The tax benefits for commercial PV systems are huge, yet current US rebate policies are focused on models suited to the economics of residential customers. A rebate given to a business is subtracted from the purchase price to calculate the tax credit and deduction. Thus the rebate actually partly replaces the deductions. The result is that every $1,000,000 of rebate money only benefits the commercial customer $550,000. This is no loss to the commercial customer, but a terrific waste for those who are paying the rebate. SMUD's solar program goal of $4/watt for installed PV is already achievable if the current tax policies are considered in economic and financial analyses. Here is a table based on our preliminary spreadsheet modeling of PV system costs showing the effect of tax deductions[18]:

Sector	Installed cost/watt	Installed tax benefit/watt	Net cost
Residential retrofit	$9.50	$0.00	$9.50
Medium Commercial	$8.50	$3.83	$4.67
Public (w/PUC rebate)	$7.50	$0.00	$7.50
Large Commercial	$7.50	$3.38	$4.13

Tax benefits for homeowners are usually only on the interest, and are at the tax rate of the PV purchaser. An additional California state tax credit for photovoltaics was set at 15% a few years ago, and reduced to the current amount of 7.5%. This credit is set to expire at the end of 2005.

SMUD customers also pay sales tax on electricity purchased from the utility, at the rate of 2.5% in the county, and 7.5% in the City of Sacramento. The city contains about 40% of SMUD's customers, and represents a significant added value for customers who purchase PV systems and will not have to pay tax on the portion of electricity they generate for themselves.[19] If the PV systems are owned by SMUD or a third party, this savings will not apply if the electricity is resold to customers and thus must be taxed.

K. Allocation of Value

Understanding and attributing value to photovoltaic electricity requires looking at any transaction from at least three points of view: SMUD as a buyer and seller of electricity, SMUD as a subsidizer of photovoltaics, and the purchaser of a PV system.

<u>Buyer and Seller of Electricity:</u> SMUD may need to assess the value of PV to its system to help justify funds for a PBI program. Stacked benefits to the power grid are one issue as described in a December 2002 study by Tom Hoff for SMUD.[20] Another issue is whether the Time-of-Use billing value will be included explicitly in the value of PV. Another issue is how the cost of peak/premium generation power purchases is considered in relation to the cost of PV power. We have already mentioned how the existing customer owned PV power in the SMUD service territory could benefit SMUD by being counted toward fulfilling their renewable portfolio standard. Establishing an internal "Green-Tag" purchase agreement between SMUD and its customers or a third party PV power supplier would be one way to account for this, as well as recognize a real value in markets that are being set up in California and internationally.

A PBI program provides an opportunity for the value of solar electricity to be considered by the power purchasing department inside SMUD. PV electricity generation can be measured correctly and accounted for explicitly in SMUD's generation mix. Addressing the concerns of power purchasers should be integrated into the program design to the extent feasible. Some of these concerns are addressed in Section 7, Value Criteria.

Subsidy Program: A PBI program offers several opportunities for benefits to SMUD's PV subsidy program. By stretching out payments over a period of years, a much faster PV scale-up is possible. And by valuing Green Power, the door is opened for cooperation from power purchasers.

Purchaser: The benefits of the value of the electricity can be given directly to the customer for PV systems owned by them. An assessment of this delivered value needs to be made and updated by SMUD as part of the accounting and PBI payment process. Shifting the balance of megawatts toward a commercial orientation would take advantage of the major tax and scale benefits available there, as has been mentioned. But, there are also ramifications for other types of purchasers.

A well designed PBI program can go beyond preserving existing opportunities for homeowners through encouraging new home markets (as is currently done), as well as the possibility for community-oriented solar projects. One of the people we interviewed who was involved in managing a PBI program mentioned a community-oriented program that installed a large PV system at a freeway exchange. Customers could purchase shares in this commonly owned PV system. This realized considerable economy when compared with each customer buying their own PV system. Another community solar facility, called Solar One, was built in Arizona in 1985 outside of Phoenix for a housing development. The developer negotiated a deal with the utility company where residents in the community shared the benefits of the power produced by the central community facility.[21] We believe that this could be a promising option for a PBI program addressing the needs of residential and commercial customers. A cooperative venture, where a facility might be built on the roof of a large commercial structure could have 'shares" available for local residents. This arrangement could lower the unit cost for both parties, and provide a secure and out-of-sight location for homeowners concerned about the aesthetics of solar modules on their roof. This model can be developed further when programs are designed for specific market sectors.

L. Administration

The PBI program administration should be carried out by SMUD. A feed-in tariff that buys the PV electricity would have to be managed by those responsible for power purchases in SMUD. A Premium Value Payment program would more likely be run within the PV program itself. Both would require cooperation between departments, as an important goal would be to include PV production in SMUD's RPS.

Automated communication between PV output measurements, monitoring these for O&M needs, accounting for SMUD renewable generation, and the billing and payment systems would greatly simplify program administration. SMUD should examine whether it is interested in administering a larger scale loan program, or whether this should be funded by SMUD but administered by a bank. It would also be helpful for SMUD to be the party to help customers figure out the economics and tax benefits for PV systems that they might purchase. Providing a Quick Quotes "consulting" service for customers interested in PV is one way to meet this need.

M. Integration of PV

Diversifying SMUD's future supply mix to avoid shortages, rate hikes, and fuel price increase means that installed PV systems must be integrated into SMUD's general procurement process, rather than a separately administered subsidy program. If increasing locally-sited generation is to actually decrease SMUD's reliance on external transmission, and to provide grid and voltage support in critical service areas, SMUD's PBI program must get results not merely at the site meter level, but at the interval meter and substation levels— it must actually reduce SMUD's daily procurement of peak power from across the grid.

Integration of program components ultimately underscores integration of PV into SMUD's procurement processes. To achieve real local and regional environmental benefits from SMUD's solar programs, SMUD's PBI must physically remove electrical load at the substation level and thus eliminate the need for SMUD to purchase or build conventional generation, transmission and distribution capacity to serve that load. In particular, a sustainable PBI program must lower the cost of serving SMUD customers by physically reducing per capita peak usage in a manner that allows for less SMUD procurement of peak capacity and fuels— a result that Pioneer I and II have never quite produced, but a well-designed feed-in tariff could deliver.

A PBI program might need other layers of integration to be successful, such as in contracting. Market conditions at the time of implementation will determine whether financial savings can be had by large scale purchases. Having numerous contractors could complicate this, both in terms of getting the price breaks and practical administration. It may be necessary to have a single overall contractor to take advantage of large scale purchase agreements for equipment at lower prices or better terms.

5. American PBI Programs

This section describes four ongoing American PV incentive programs in Massachusetts, Pennsylvania, and Connecticut that contain performance based incentive elements and a fourth pilot program proposed by the CEC in California to be implemented in early 2005. The program descriptions are summarized, organized, and evaluated, to the extent possible, around the program elements described in Section 4 above.

1. Massachusetts Solar-to-Market Initiative

Program Description:
This hybrid incentive program was initiated in late 2002 with a solicitation for proposals when there were only 165 PV systems in all of MA totaling 470 kW of PV capacity. In the first round of proposals targeted at clustering PV installations (essentially by issuing an exclusive franchise in a geographic area), they awarded 6 out of 10 proposals in January 2003. In the second round of open (non clustered) installations, they awarded 13 of 19 proposals. Their intent was to attract and fund different PV business and marketing models. 5 of the 19 were larger scale single site systems (e.g., Harvard Business School, Big Box retail shopping center, museum, schools, churches, fire station); 1 was for 45 residential retrofits (1-2 kW) attempting to implement the clustered marketing strategy using a Model T Ford production line approach, and there were several small single installations. The Solar-to-Market Initiative was designed as an initial 2-year pilot program. Most of the systems have been installed but a few have been granted completion extensions into 2005.

- **Program Elements**
  - Payment level– Hybrid program where 70% of a $5/watt incentive is paid up-front with the remaining 30% paid down quarterly over 3 years at a rate of $0.38/kWh. Commercial systems received $4/w with a $0.30/kWh performance payment.
  - Payment term– 3 years
  - Performance incentive– $0.38/kWh is based on an assumed 15% CF over 3 years (no risk premium was included as the rate was set at just parity with the NPV of the 30% capacity incentive). If the actual CF exceeds 15%, the full incentive is paid (capped at 30% cap of the $5/w) in less than 3 years. If the CF is less than 15%, less than the full incentive will be paid.
  - Participation restrictions– no requirements on system size and all customer classes were eligible
- **Marketing Strategies:** Clustered market sector- one of the program goals was to try to encourage proposals incorporating targeted geographic clusters to reduce program and

system costs through concentrated marketing activities, system standardization, volume purchases, clustered installations, and coordinated interconnection and permitting. This goal generally was not achieved as some solar integrators trying to implement it found they had to significantly modify or abandon the concept entirely. One participant was able to negotiate a discounted bulk one year purchase of PV equipment but wasn't able to install systems fast enough to take full advantage of it. This clustering concept has the potential of shoring up weak portions of the local utility distribution grid although the program was not specifically designed to achieve this goal.

- **Program subscription:** the program closed for new grants in 2004 after 2 years since it was designed as an initial pilot program and all the program funding was allocated. During that time, about 280 (240 of which were residential) new installations were added in 90 cities and towns amounting to about 900 kW of new PV capacity
- **Funding source:** a statewide system benefits charge levied on all electric bills and is administered by the Renewable Energy Trust. Average monthly residential customer charge is about $0.35.
- **Program funding:** $4.2M which was allocated to 19 grants.
- **Supporting programs:** A loan fund for PV companies for technology development and business expansion. This program didn't work very well because its threshold qualification criteria were too strict for small businesses and larger businesses had access to more attractive capital.
- **Program performance:** Overall the PV systems in the program exceeded the 15% CF assumed for the incentive payment calculation (CF varied from 9% to 18%)- only a handful of systems did not meet the 15% CF assumption. Selected system performances are included on their web site.
- **Supporting design/installation/equipment standards:** See solicitation for details. A separate meter was required.
- **Other features**
  - Production and tracking contractor was funded for $300,000 to track and provide documentation on performance of the program.
  - Installer training certification program was offered
  - Similar "open installations program" that won't require clustering and will provide lower incentive levels for new buildings than existing buildings
- **Program evaluation**
  - Successful features– program manager feels that the 30% performance incentive based on the 15% CF monitoring requirement did encourage better designed, operated, and maintained PV systems. However, it is an administrative burden to compile and analyze all the monitoring data prior to approving the incentive

payments. They may do some post audit case studies next year to assess the viability of some of the program features.

- Problems requiring program changes– future programs may require a one year performance term to reduce the administrative burden and will probably reduce the % of the performance payment from 30% to 5-10%. PV integrator participants found that a 30% hold back was hard to sell to customers. The clustering concept was considered a flop overall since the only successful clusters were those run by local community energy action groups. One proposal involved a 1 kW "one size fits all" concept (standardized package design) for 100 residential retrofits which was quickly modified due to marketing difficulties. They might lower the 15% CF assumption somewhat since some interested bidders thought that was too optimistic. They will explore structuring future programs to allow small generators to sell their RECs. They also will explore working with local utilities to design a program that considers a congestion relief model for substations and feeder lines that are overtaxed.

- **Features/experience relevant to consider for SMUD**
  - Clustered target market possibly based on distribution system weaknesses or other geographic factors may be worth exploring
  - Programs should be simple to administer
  - Hybrid PBI programs designed for parity with a Buydown $/kW incentive are hard to sell— a premium may need to be included in the PBI incentive
  - Setting a realistic PV system performance standard seems to have an effect on the performance of qualifying systems

- **References**

1. Bolinger and Wiser, LBL, 9/2002, "The Use of Capital- and Performance-Based Buy-Down Programs for PV in CA, PA, and MA
2. www.masstech.org/renewableenergy/solar_to_market.htm
3. Phone interview with Sam Nutter, 12/8/05

- **Program Contact:** Sam Nutter, Massachusetts Technology Center, 508 870 0312, nutter@masstech.org

2. Pennsylvania Programs

2.1 Sustainable Development Fund (SDF) Solar PV Grant Program

This program was initiated in December 2001 and offers grants for PV systems purchased by PECO Energy distribution company customers.

- **Program Elements**
    - Payment level– Hybrid program with a Buy-down incentive of $4/watt (rated PV capacity @STC) up to $20,000 (through 12/31/04), then $3/watt up to $15,000.
    - Payment term– 1 year, the meter is read at the end of the first year and a payment is made based on the kWh
    - Performance incentives– $1/kWh of gross solar production at the end of the first year up to $5,000 paid to the PV system owner (this equates to $1/kW for a 2 kw system making the total rebate $4/w). In addition, a $0.10/kWh of gross solar production in the first year up to $250 is paid to the participating contractor. These PBIs are intended to give the owner and installer a significant incentive to monitor system performance and to make certain it is performing well.
    - Participation restrictions– eligible system size is between 1 kW to 5 kW, open to all customer classes, maximum rebate is $25,000 or 80% of the total installed PV system cost
    - Renewable Energy Credits– They are not buying the RECs but the program administrator was uncertain how they were being handled
- **Marketing Strategies:** Since they are trying to conserve their limited funds they have not been actively marketing the program except by their web site and word of mouth. They have spent $2M of the $4M program funding available and will have to find better ways to market the remainder of the program since program interest is tapering off.
- **Program subscription:** As of 12/04, 60 PV systems have been installed for a total capacity of about 300 kW with another 25 applications pending.
- **Funding source:** Part of a one-time settlement with PEPO during the deregulation. process. The settlement resulted in $4M for a PV program and $12M for a wind program
- **Program funding:** $4M of which about $2M has already been expended
- **Supporting programs:** None, they explored allocating some of the $4M to Buydown the interest rate on a commercial mortgage loan but did not implement this feature
- **Program performance:** Average is about 1000 kwh-yr/kw for an ideal orientation expected performance of 1200 kwh-yr/kw. A 2-axis tracker achieved 1500 kwh-yr/kw.
- **Supporting design/installation/equipment standards:** all systems must meet the program's hardware and installation standards and be installed by participating

contractors (see web site below). The placement and orientation of PV modules must produce not less than 70% (conservative ac system rating based on STC nameplate capacity) of the optimal production as determined by NREL's PWWATTS program with Solar Pathfinder input. Separate meter is required.

- **Other features**
  - Program administration was outsourced for $80,000
- **Program evaluation**
  - Successful features: Customers pay attention to system operation and maintenance.
  - Problems requiring program change:
    - $250 performance incentive for contractors was too low- program administrator indicated an increase to at least $500, and probably more, would be needed for it to be a real incentive
    - Administrative costs were burdensome since the program administrator had to read all the meters on site. The Conservation Services Group in Massachusetts has a simple remote data logger than can be easily coupled with a revenue meter to transmit performance data to a web site; they may explore using this for future programs.
    - Some owners and contractors tried to negotiate for an accelerated up front payment of the PBI portion
- **Features/experience relevant to consider for SMUD**
  - PBI incentives have a potential role in incentivizing integrators/installers if the rate is high enough
  - The PBI program needs to be designed to keep administrative costs to a minimum
  - Integration of RECs should be explicitly addressed
- **References**

1. Bolinger and Wiser, LBL, 9/2002, "The Use of Capital- and Performance-Based Buy-Down Programs for PV in CA, PA, and MA
2. http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=PA02F&state=PA&CurrentPageID=1
3. http://www.trfund.com/sdf/solarpv/index.htm
4. Http://www.trfund.com/sdf/solarpv/PV_Prog_Des.htm#IS

- **Program Contacts–** Roger Clark, The Sustainable Development Fund, 215 925 1130, clarkr@trfund.com; Program Administrator – Ron Celentano, 215 836 9958, celentanor@aol.com

2.2 The Energy Cooperative (ECAP) Solar Energy Buy-back Program.

This is an electricity cooperative in the Philadelphia area with 6500 members of whom 5500 are brown power purchasers, 1000 are green buying their EcoChoice product including 21 solar customers. The ECAP is the first non-utility competitive supplier in the US to institute a residential solar energy purchase program with its customers.

- **<u>Program Elements</u>**
  - <u>Payment term:</u> 2 year contract, with monthly payments based on monthly separate dual meter readings (one for electricity purchased billed at 7.25 cents/kWh and one for the PV production paid at 20 cents/kWh)
  - <u>Performance incentives:</u> $0.20/kWh for PV system output
  - <u>Participation restrictions:</u> eligible system size is between 1 kW to 5 kW, open to commercial and residential customer classes- only customers who are part of the Solar Development Fund PV Grant Program are eligible
- **<u>Marketing Strategies:</u>** Co-op web page, local newspapers, word of mouth, SDF referrals, PV installers— they do not use bill stuffers
- **<u>Program subscription:</u>** As of 2/12/04, 21 PV systems have been participating for a total of about 75 kW installed
- **<u>Funding source:</u>** Funded from green power premium payments from 1000 EcoChoice customers who are paying currently a premium or 1.25 cents/kWh over the brown power rate but with the new rate structure will only be paying a premium of .50 cents/kWh. They are concerned about losing Eco Choice customers so are reducing the premium and hence the funding for the PV program.
- **<u>Program funding:</u>** Very small since it is based on 1000 residential customers who will pay a green power premium of .50 cents/kWh with the new rate tariffs
- **<u>Supporting programs:</u>** Sustainable Development Fund PV Grant Program for PEPO customers (see separate discussion)
- **<u>Program performance:</u>** participation doubled since last year. Based on case studies on their web site, system performances ranged from a low of 745 kwh-yr/kw to 1037 kwh-yr/kw, with a single axis tracking system performing worse than a fixed system (1000 kwh-yr/kw). Thus performance improvements do not seem to be a motivation for this program.
- **<u>Supporting design/installation/equipment standards:</u>** must meet specifications developed by the Sustainable Development Fund's solar grant program. Require 3 meters (PV, utility in, utility out)

- **Other features**:
    - Customers must purchase the Co-op's "EcoChoice 100" Green-e certified product for their residual energy
- **Program evaluation:**
    - Successful features: PV visibility as part of their Eco Choice product
    - Problems requiring program changes: Geographic distribution of the systems requires lengthy access times, program is very small due to the funding mechanism
- **Features/experience relevant to consider for SMUD:**
    - Innovative linkage with the Co-op's green energy product
    - Co-op purchases PV power at greater than retail rate as opposed to providing a performance incentive payment (need to find out on which side of the meter the PV is connected.)
- **References**

1. http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=PA02F&state=PA&CurrentPageID=1
2. http://www.theenergy.coop/solar_buy.htm
3. http://www.phillysolar.org/PV

- **Program Contacts–** Nathalie Shapiro, The Energy Cooperative, Philadelphia, PA, 215 413 2122, nshapiro@theenergy.coop

3. Connecticut Clean Energy Fund, Photovoltaic Program for Solar PV Installations on Commercial, Industrial, and Institutional Buildings.

This grant program was issued in December, 2003 and modified in September 2004.

- **Program Elements**
  - Payment level: Hybrid grant program with Buy-down incentive of $5/watt (PTC capacity based on PVUSA Test Conditions) with 90% paid upon successful installation, commissioning, and inspection and 10% holdback based on 6-month performance. An additional $0.75/watt is provided for battery backup systems.
  - Payment term: 6 months (see above).
  - Performance incentives: Second payment of 10% made after the 6-month anniversary provided the system has produced at least 70% of the projected AC energy production as verified by a CCEF independent consulting engineer.
  - Participation restrictions – eligible system size is greater than 5 kW, open commercial, industrial, schools, local/state/federal government, institutional organizations
  - No system size limitation except they must be greater than 5 kW
- **Marketing strategies:** web page
- **Program subscription:** unknown
- **Funding source:** public benefits fund
- **Program funding:** $3M over 3 years
- **Supporting programs:** none
- **Program performance:** unknown
- **Supporting design/installation/equipment standards:** all systems must meet the program's hardware and installation standards and include a 5-year full warranty to the purchaser.
- **Other features**
  - Real time and historical system operating data must be made available to the public through the Internet
  - Where possible, the project should be made available for educational programs
  - They don't retain ownership of the RECs

- **Program evaluation:** unknown
- **Features/experience relevant to consider for SMUD**
  - Real time Internet monitoring
- **References**
  1. 1.http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=CT08F&state=CT&CurrentPageID=1
  2. http://www.ctcleanenergy.com/documents/CIIPVRFP91504V2.pdf
- **Program Contacts–** Charlie Moret, 860 563 0015 charlie.moret@ctinnovations.com

4. California CEC PBI Pilot Program

This pilot program is currently in the final stages of development and is expected to be implemented in Q1 of 2005. The features presented below are those that were presented in a CEC committee workshop on 12/1/04 entitled "Emerging Renewables Program Proposed Guidebook Changes" and in the Decision Document cited below.

- **Program Elements**:
  - Payment level– None upfront; this is a pure PBI
  - Payment term– for 3 successive years of uninterrupted performance
  - Performance incentive– Single incentive level of $0.35 per kWh paid monthly (the $0.35/kWh level accounts for the full tax benefits available to commercial customers and supposedly is designed to be equivalent to the current buy-down rebate level on a NPV basis)
  - Participation restrictions– Open to all customer classes although incentive payment includes the value of tax credits and depreciation only available to commercial customers
  - Funding capped at $400k for any single installation with $1M cap for any corporate or government parent
  - No minimum or maximum system size limit
  - 12 month reservation period for system installation
  - Reservation amount will be calculated based on a 25% CF, PTC system rating, $0.35/kWh, and 3 years PV output
- **Marketing Strategies:** CEC web site, California solar industry
- **Program subscription:** pilot program in the final stages of development. CEC approval expected in 1-05 with implementation within 1 month
- **Funding Source:** California Emerging Renewable Energy Program
- **Program funding:** $10 Million

- **Supporting programs:**
  - Will run concurrent with other rebate programs
  - No loan program or financing element will be included
  - Incentives under the PBI program cannot be combined and cannot be used with other funding under the ERP or Self Generation Incentive Program
- **Program performance/goals:** No performance data available as yet since it won't be implemented until early 2005. Program objectives are to: extend ratepayer funds, determine appropriate incentive level, attract optimal PV systems and installations and encourage good maintenance, and test program strategy for maximizing PV production
- **Supporting design/installation/equipment standards:** Revenue grade meter required, performance data reporting must use either a 3rd party web-based reporting system or a utility reading and reporting system- applicants are responsible for all costs of the meter and reporting system.
- **Comments raised at 8-27-04 and 12-1-04 Workshops**
  - Tor Allen, Rahus Institute: Advantages of PBI include the following:
    - Potential to provide greater incentives to projects that provide greater peak value to a utility (e.g., west facing systems) and T&D benefits in capacity constrained areas
    - Potential to provide some $/kWh compensation for RECs in a bundled PBI rate while using the same meter reading for both purposes (City of Palo Alto Utility pays up to 5 cents/kWh for solar RECs as part of their green power program)
    - Payment term should be 10 years which matches the construction defect warranty term for new home construction and would provide a motivation for inverter manufacturers to extend their warranty period
    - PBI rate should be $.25/kWh added to the average net metering benefit rate of $0.15/kWh for a total of $0.40/kWh resulting in a simple payback period of 10 years
    - A basic PBI price should be established for all customer classes and the premiums can be added for various elements such as REC purchase, utility peak value such as west facing installations, capacity constrained T&D areas, and other utility values
    - Recommends against running a pilot PBI program concurrent with a capacity-based incentive program as it will distort program evaluation results and increase administrative costs.
    - Recommends one PBI rate for all customer classes

- **<u>Program evaluation:</u>**
    - The program will be evaluated after 1 year. Program participants must agree to participate in an evaluation process.

- **<u>Features/experience relevant to consider for SMUD</u>**:
    - Whatever PBI pilot program is ultimately implemented in early 2005, data on participant subscriptions should be available before SMUD plans to implement its program since whenever a new pot of funding money is made available, those incentivized by it usually apply soon after the program is introduced. Thus no matter how poorly or how well designed the program is, there should be some data useful to the design of the SMUD program.

- **References**

    - Decision Document Pilot Performance-Based Incentive Program, CEC
    - Draft Guidebook, Emerging Renewables Program, Fourth Edition, CEC, January 2005, CEC-300-2005-001-ED4D
    - ERP Proposed Guidebook Changes, Committee Workshop slide presentation, 12/1/04
    - Pilot Performance-Based Incentive Program Proposal, Staff Draft
    - Comments on the Accelerated Development Renewable Energy Draft White Paper, 8-27-04 Workshop, Distributed PV, Tor Allen, The Rahus Institute, 9/6/04
    - Comments on Proposed Guidebook Changes and Pilot Program, Fred Bloom, GenSelf, 11/30/04

6. German and Other European PBI Programs

The traditional PBI tariff employs an extremely (by American standards) generous payment for power output in order to achieve a high level of security for the buyer as well as those who are committed to the photovoltaic program goals. Under the "Aachen model" adopted by some 20 cities throughout northwest Germany during the 1990's under North Rhine-Westphalia regulations (subsequently adopted by most of the other German states), "full cost rates" (FCRs) were created for newly installed photovoltaic systems in order to fully reimburse the money invested by a resident or business in a grid-connected photovoltaic system. By purchasing the solar electricity fed into the public grid at a sufficiently high price, the FCR allows the PV owner to finance (including interest rates associated with borrowed capital) and maintain the photovoltaic system until its financial life cycle is complete. No Buydown or other subsidies were employed. The calculation of the PBI payback rate was made by estimating the amount of electricity produced by an optimized model system over its (20 year) lifetime. From this model was derived a price per kilowatt hour that should fully reimburse the PBI PV owner over the life of the system.

The problem presented by the Aachen model FCR is that the resulting tariffs were very high— as high as a dollar per kilowatt hour. In Germany, the supervisory authority that sets electricity rates in North Rhine-Westphalia established a payback rate of 1.89 Deutsche Mark (DM) per kilowatt hour for solar energy (since 1.1.1999 only 1.76 DM/kWh). The authority accepted a total increase of the electricity rates of 1% to fund this PBI program. As the costs for solar systems decrease over time, later adopters of newly built PV plants will receive lower payback rates for their metered output; as of January 1st, 1997, full cost rates dropped from their previous level of 2.00 DM/kWh to 1.89 DM/kWh and as of January 1st, 1999 down to 1.76 DM/kWh. More recently, the German Parliament (Bundestag) approved an Act Revising the Legislation on Renewable Energy Sources in the Electricity Sector (July 21, 2004) which established a federal PBI tariff at approximately 49 cents/kWh (Euro) which, while significantly lower than Aachen, is still quite high by US Standards, reflecting the political and economic benefits of largely government-owned or government-controlled German electric utilities.

Zero interest loans were a major component of the Hundred Thousand Roof Program, but the interest rate subsequently raised to 1.8%.

A number of other European Countries have also adopted Feed-in Tariffs. Higher rates are ordinarily set for smaller systems, and some renewable energy laws provide for special high pricing during peak billing, such as in Switzerland. The IEA Database lists 16 member countries that have Feed-in Tariffs, though some of these such as Canada and Denmark are for renewables such as wind or biomass and not photovoltaics. Some national laws state the right to receive basic cost recovery over a specified period. The Czech Republic, for example, guarantees cost recovery and a basic profit over 15 years for photovoltaic installations. Electrical companies must buy 8 percent of their power in the form of renewables or face penalties. France has a hybrid system which pays 4.6 Euros per watt and then 1.5 cents/kwh thereafter as a subsidy. Rates in Overseas Departments (such as Corsica) receive 30.5 cents (Euro)/kwh. Some countries offer very low rates (1 to 10 cents/kwh) while others are generous. Here is a sampling of feed-in tariff rates in selected European countries.[22]

Country	Low	High
Netherlands		€0.068
Geneva, Switz.	0.6 CHF	0.9 CHF
Italy		€0.22
Portugal	€0.284	€0.499
Spain	€0.22	€0.39

7. Value Criteria

A discussion of the value and price of photovoltaics

Photovoltaic electricity costs more than the rates charged by most utilities to customers. A workable Performance-Based Incentive needs to allow the purchasers of PV systems, at a minimum, to recover the excess cost over the perceived value. In addition, there needs to be a premium that motivates action. This premium is defined in subjective terms of perception because different actors will, in any market, perceive value and cost in different terms. Studies have found that many customers in the US are willing to pay a premium for products they believe to be beneficial to the environment, because they value the environment, not because the environment has a set price.

For PV the role of perceived value is also relevant. An example of perceived value deals with the fact that many customers have to redo their roof in order to install PV systems. Yet, the cost of reroofing is not generally considered part of the cost of photovoltaic systems. One reason for this is because customers consider the new roof to be worth its full cost, and they are presumably paying the normal market rate to do so. Yet it is also undeniable that some do so sooner than they otherwise would have. This is due to the excess value they place on the PV system over its market cost. Part of this premium is undoubtedly based on the fact that they are told the PV panels will help protect their new roof and make it last longer, which it may well do.

German solar advocates have pointed out that utilities routinely purchase electricity supplies at a premium similar or even higher than that commanded by photovoltaics. This fact demonstrates that objections to photovoltaics on the grounds that it "costs too much" are not consistent with other price decisions that power purchasers routinely make. While most commodities decrease in value to the buyer as more are purchased (the Law of Diminishing Returns), electricity turns normal economics upside down— power purchasers are willing to pay a premium for energy sources because the last megawatt hour of electricity is worth far more than the first: it is the last megawatt or its lack thereof that buttresses or collapses the entire utility power grid. High priced electricity is affordable because expensive purchases are diluted in the cost of the total mix of generation sources. The same argument can be made for photovoltaic power, yet the argument will have its greatest effect when utility power purchasers value and account for PV in the same way they do other sources of premium power.

The rate impact of supplying a community with PV electricity, especially one in sun-rich California, can be made very small. A most ambitious program, such as a 50 Megawatt goal for Sacramento, would likely provide less than one percent of the total electricity supply. If the cost were as much as double the prevailing delivered rates, its dilution would affect all customers only by about one percent on their bill. Yet, it is entirely possible to take advantage of a number of elements that bring PV electricity quite close to the cost of delivered power, especially over a longer period of time. These include tax breaks, economies of scale and performance standards, in combination with accounting for the extra value of electricity during times of peak demand, as well as the general effect of escalating electric rates over the next decades.

PV Value Factors

A number of factors affect the value of photovoltaics. These include the benefits specific to distributed generation, such as the avoided costs of central power station generation, as well as the cost of transmission and distribution. These have not only direct financial costs such as fuel and capital expenses for generation, but also indirect ones such as the physical losses of electricity in the distribution and transmission system. In general, the overall sum of these costs is implicitly included in the electric bill, and for this reason the cost of delivered electricity can be considered a baseline of "floor value" for electricity generated by a PV system that is located on a customer's property.

There are, in addition to the baseline value of PV, elements that represent a premium above the delivered price. One example is the value to the customer in avoiding a tax on delivered electricity. In Sacramento County this electricity tax is .25 cents/kWh, while the city of Sacramento imposes a tax of .75 cents/kWh. These taxes are on the full bill, including demand and monthly service fees. A second premium is associated with the avoided costs to SMUD for expenses for transmission, distribution and generation which would not have to be paid if distributed generation were in place. Estimates for the distributed generation premium value in SMUD's territory have been calculated to be near 1 cent/kWh.

Some value elements are unique to the specific nature of photovoltaics. These have to do with the time of day, and the seasons of the year when solar power is available. Solar energy provides much more power during the summer than the winter, and summer electric rates are usually higher. Photovoltaic systems benefit from this match of the solar resource with the system load. In addition, daytime is when electrical demand increases and purchasing power is more expensive to meet the system peak. Rates paid by customers reflect this fact to some degree by increasing during the peak demand times of the day. On hot summer days SMUD must buy power to meet the high demand on the spot market, often at a premium that would not be covered by the customers bill (particularly when transmission and distribution costs are added). For this reason solar power can have a premium value both for the customer and for SMUD.

Not all sun hours are valued alike, as demand is not so high on summer mornings as it is in the late afternoon. The demand level during the day begins to rise before sunrise, peaks sometime between noon and six p.m. (depending on the weather, the time of year and day of the week), and then falls off during the evening.

Effective Load Carrying Capacity of Photovoltaic Systems

One of the value-added benefits frequently attributed to PV systems is that their output is generally coincident with the peak demand during the sunny part of the day, and during the higher demand in the summertime. Some regions do not actually reach their annual peak in the summer season. San Francisco, for example, has a mild climate and reaches its peak in the fall.

However, Sacramento, in the hot California central valley, has its peak in the summer, as the heat of the day creates a high demand due to air conditioners running at this time. This demand for electricity that is specifically dependent upon the heat caused by sunny days increases the dependability and value of solar generated electricity.

There are a few dimensions that have been identified that can increase this value of PV:

- The ratio of summer to winter peak daytime demand corresponding to the ratio of solar resource in a given region in the same seasons,
- The daily demand curve and its correlation to photovoltaic output
- Conservation strategies that complement the photovoltaic output

Research shows that not all regions with good sun have good correlation between demand and solar output. Southern California and the Midwest have better seasonal correlation than the Southwest states and Florida. Daily demand curves, however, can be even more localized in their character. The ISO region in California has peak demand in the mid-afternoon during the late spring. By late summer this can come as late as 5:00 in the afternoon, with high demand persisting well into the evening.

This late daily peak demand poses a special problem for photovoltaic systems. Optimal annual output is generated by pointing the panels due South. So, if we want to maximize annual kilowatt-hours this is how they must be oriented. On the other hand, if we want to incorporate the value of peak demand in Sacramento during the summer then we need to point the panels to the West. While most of the year would be optimized by a Southwest orientation, the hottest part of the Summer requires pointing them almost due West. This, of course, is the period when transmission and distribution systems are most likely to be strained, and spot power prices soar. Thus, pointing the panels West, in Sacramento, is the best value from the standpoint of when it is needed to cover expensive peak power. If a relatively small amount of photovoltaic power could even prevent one rolling blackout, it would justify the expense.

On the other hand, this orientation comes at a significant cost. If the panels are placed on a 45 degree sloping roof pointed due West, then they are sacrificing about 22 percent of their total output. (source: Endecon Engineering) Some studies have confirmed an optimal orientation of 30 degrees West of South to gain the benefit of both coincidence with the peak system demand and the annual solar resource.

Value of Support for PV Programs

We have considered a few factors that affect the value of delivered PV power, but there are also value components that have to do with how PV is subsidized or paid for. We will briefly look at three of these.

Value of Rebates vs. PBIs

Commercial facilities that are gas customers of PG&E can apply for PUC Self-Generation rebates, but these carry rules that exclude participation in other payment programs. The rebate, which is only for PV systems over 30 kw, was lowered to $3.50/watt in December 2004. As these subsidies displace commercial tax credits and depreciation, the actual incremental value is less, as shown in the table below.

year	PUC rebate	After-tax Value
2004	$4.50	$2.48
2005	$3.50	$1.93
2006	$3.00	$1.65

Net Present Value

The payment of a Feed-in Tariff over a period of years comes at a cost, since future payments are made in money that is valued less than present money. The comparison with an upfront payment is thus at a disadvantage from this point of view. Yet, as is clear from the tax considerations, other factors also play a role. It is essential to keep in mind that interest rates define the rate of decrease of future payments versus present ones. This underscores the importance of lowering the cost of money over time, which is the interest rate on a loan.

Net Metering and the "Electricity Value Slope"

Net-metering involves valuing excess PV electricity sent back into the grid at the same rate as the customer's retail electricity rate. However, this is a big problem for utility power purchasers who do not like the idea of paying retail prices for electricity, and who must incur further distribution costs that cannot be recouped. If we view the whole energy process, from getting fuel out of the ground to final customer, there is an increase in value at every level. The lowest cost for energy is at the mine or gas wellhead. The cost for the same fuel is much higher by the time it reaches the power plant, and higher still when it leaves the power plant in the form of electricity. Thus energy climbs up a sloping hill of value until it reaches the consumer. Selling electricity back into the grid from the consumer is a downhill affair from economic value viewpoint, and contradicts the basic instinct of power purchasers. A PBI system can be structured to meter PV power separately and thus eliminate the net-meter. If PV systems are sized to allow full consumption of power on-site, then the backwards PV electricity distribution problem is eliminated and power purchasers should be happier. It should thus be a principle of a PBI program to send as little power as possible in a direction of decreasing value, and instead take best advantage of the increasing value slope by selling PV power where it is worth the most.

8. Conclusions

> Another of SMUD's core values is to actively work to promote the benefits of local ownership in the community.
>
> ~*SMUD 2004 General Manager Budget Letter*, p.5

SMUD's PBI program could redefine the utility's role in PV from a steward and subsidizer to a purchaser of system output. This "output" is really a variety of components that are of value to SMUD. These components include the benefits of distributed generation, but not just this. SMUD is also committed to meeting RPS goals, and PV can and should contribute to this. We have mentioned a local Green-Tag system by which SMUD could purchase renewable credits from its customers as a way that SMUD could pay for and receive RPS credits. In order for SMUD's solar installations to contribute to meeting RPS goals, all systems must be equipped with utility-grade time-of-use meters and automated meter-reading equipment. Measurement and monetization of distribution, transmission and peak generation system benefits should form basic design criteria in SMUD's PBI program.

Another important goal of SMUD is to have locally sited and owned generation, for which PV is a perfect match. This too should have value to SMUD as other sources of generation that are local carry price risks that PV does not. A long-term view acknowledges that rising fuel and electricity costs place a premium value on current investments that have a fixed long-term cost.

SMUD District's goals focus on lowering cost and raising the standard of performance for installed systems, as well as the phasing out of subsidies. PBIs create incentives to increase performance, but module performance alone is not good enough. Further improvements require adequate scale of installations and purchases, taking advantage of tax benefits, the financing leverage that SMUD possesses and its market power. To foster the development of a self-sustaining PV market in Sacramento while adhering to SMUD's own business aims, SMUD has the opportunity to develop more than a smattering of more efficient customer self-generation. SMUD has the opportunity to bolster its reputation as a leader in solar energy and to create a program that will realistically make PV into a cost-effective, clean, distributed, locally owned energy resource.

Endnotes

1. *A Guide to the Photovoltaic Revolution*, Maycock and Stirewalt, Rodale Press, 1985, p. 96

2. *Who Owns the Sun*, Berman and O'Connor, Chelsea Green Publishing Co., 1996, pp. 183-186.

3. Exchange rates used here for January 2005 are $1.30 to the Euro.

4. Insolation in Germany ranges between 900 kwh/kw/yr in the North to 1200 kwh/kw/yr in the South on a flat surface (source: Solarhydrogen.com), while Sacramento has 1789 kwh/kw/yr insolation (US DOE). This means solar electricity costs should be 40% less on average, or 43 cents/kWh in Sacramento, assuming equivalent capital and O&M costs. One should keep in mind that this pays back the system in 20 years, though a PV system will produce for years beyond this at very low cost.

5. The German national law instituted payments for all renewables at 90 percent of the delivered cost of electricity, while the results of PURPA were inconsistent. Some states instituted net-metering, while others allowed utilities to repay customers with PV systems at the wholesale electric rate. See: *Who Owns the Sun, by Berman and O'Connor, 1996, pp. 199 and 231.*

6. Don Aitken in *SMUD PV PROGRAM REVIEW: SMUD'S PV PROGRAM: Past, Present, and Future, FINAL REPORT, December 30, 2000*, on p.51, pointed to "A federally sponsored "PV Technology Roadmap Workshop", jointly conducted by the US Department of Energy (National Center for Photovoltaics) and the US Photovoltaics industry in June, 1999. Highlighted two recommendations for "Commercialization":

> Encourage consistent multiple-year funding
>
> Offer long-term low-interest financing for appropriate, easily integrated, reliable PV systems.

See *Report of the Photovoltaic (PV) Industry Roadmap Workshop*, Energetics, Inc., Columbia, MD, September 30, 1999"

7. A comparison with California shows that Germany has a little more than double the population, but only about 50% more total income. Oversubscribed applications for PV grants in California in 2003 was for 45 mw under CEC programs, though only 27 mw was installed (source: *PV Market Update,* in *Renewable Energy World* July-August 2004, P. Maycock*;* http://www.jxj.com/magsandj/rew/2004_04/pv_market_update.html#author). Germany installed 150 mw in 2003, a figure expected to have doubled in 2004. If the German program were scaled down to the population of SMUD's territory, the local PV installed in 2004 would have been 3.5 mw.

8. (http://www.solarbuzz.com/News/NewsNAPR450.htm).

9. Calculated performance of PV modules oriented due West on a roof sloped 30 to 45 degrees (which we have seen in the SMUD service territory, are 78 to 85% of optimal annual performance due to orientation alone. Source: The Sierra Sun, Summer/Fall edition, 2001, p. 9. Table: Orientation Factor for Annual Energy Production in Sacramento, California, Endecon Engineering.

10. Solar Modules and Photovoltaic[s], Powerpoint presentation, Benjamin Dupperthal, Production Engineer, GPV-AB; Space Science and Technology conference, Aug. 2003, sponsored by Gällivare PhotoVoltaic and UMEA Universitet. Ppt p. 45, states that a 36 cell panel with one cell shaded 75% reduces maximum power output of the panel by 70%, even though this only represents 2% of the total surface of the panel. The shaded panel acts as a resistor and can overheat, potentially damaging the cell. Another source reports that "if you have a tree or structure that is close to the array and casts a shadow on the array, then virtually 50% of the output of the shaded module or modules will be lost!" *The Solar Electric Independent Home book*, by New England Solar Electric Inc., 1998, p. 8-4.

11. Phone conversation with Sharp sales representative, Huntington Beach, CA, Dec. 2004. Sharp Solar reported flash test of its premium modules revealed equivalent life of 120 to 130 years of light cycling. Field testing in the 1990s with modules aged 1 to 12 years showed no degradation (some were reported to have improved) and most had been tested four years earlier. Source: *PV Performance Tests*, Richard Perez and Bob O'Schultze, Home Power #49,

October/November 1995. Pacific Solar reported performance of its new test modules in an award winning paper (from the 3rd World Conference on Photovoltaic Energy Conversion), *Large Area Deposition for Crystalline Silicon on Glass Modules*, by Paul A. Basore, May 16, 2003. Osaka, Japan, and none showed degradation in outdoor conditions over a 1 to 4 year period (p. 4). Rigorous laboratory cycle testing showed 20% degradation at cycles matching or exceeding other panels tested. Sunpower of Sunnyvale, Ca reported in a phone conversation in June, 2004 that the mono crystalline substrate of PV cells does not degrade after the initial "burn-in". Paul Fenn reports that academics have found evidence PV cells should last 80 years. While these tests and testimonies are not broad in a scientific sense, they are modest yet growing evidence for greater PV module longevity. Further field testing and experience is essential, but many people experienced with PV are now convinced that 30 years (the life span generally used here) is a very conservative assumption for longevity of the modules, especially for those of higher quality.

12. SMUD data on 135 residential PV systems for a one year period ending October, 2004. Some were anomolously high, recording between 1800 and two near 2700 kwh/kw/yr, the latter being more than the solar resource. But most (at least 80%) of PV systems fall within a credible range. Meters are not of revenue grade, and thus have a definite margin of error. We recommend some sort of auditing of existing PV systems and upgrading of measurement.

13. "Measured Performance of California Buydown Program Residential PV Systems", Kurt Scheuermann et. al., Regional Economic Research, Inc.

14. 2003 SMUD Annual Report, p. 19.

15. Paul Maycock in "*A Guide to the Photovoltaic Revolution", Maycock and Stirewalt, Rodale Press, 1985, p. 91*, proposed that PV would first be deployed in remote applications followed by residences and then central power generation. Don Aitken developed the Sustained Orderly Development and Commercialization (SODC) for photovoltaics in the early 1990s in a presentation to the State of California, which begins with residential, followed by commercial, community, grid support and central utility plant. Maycock's and Aitken's models are based on the cost of electricity at each point (i.e., residential electric rates are highest, commercial lower, and utility generation costs the least) and market penetration occurs as the declining price of PV can meet the cost level of each market in turn.

16. Residential PV systems in California actually increased in price during 2001, while commercial systems between 10 and 30 kW decreased $2.10/Watt. source: *The Use of Capital- and Performance-Based Buy-Down Programs for PV in California, Pennsylvania, and Massachusetts, Mark Bolinger and Ryan Wiser, September 2002*.

17. Table in DOE pub.: *Technology, Manufacturing, and Market Trends in the U.S. and International Photovoltaics Industry,* by Peter Holihan. Data: Energy Information Administration, Form EIA-63B, *"Annual Photovoltaic Module/Cell Manufacturers Survey*." Http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/fig7s.html

18. Cost per watt is approximate for sectors and illustrative. CEC installed costs show significant variability in every sector. Recent bids by Powerlight and Sunpower and Geothermal for a 1 mw project in Butte Co., CA, ranged between $7.06 and $7.58 million. Source: http://www.chicoer.com/Stories/0,1413,135~25088~2648404,00.html

19. It may prove beneficial to have this verified for SMUD by the city taxing authority, or to try to get an explicit resolution by the city council to exempt solar generation inside the city limits from taxation.

20. Final Results Report with a Determination of Stacked Benefits of Both Utility Owned and Customer Owned PV Systems, Deliverable 1.3.5.2, Tom Hoff, Clean Power Research, Dec. 10, 2002.

21. *Who Owns the Sun*, *People, Politics and the Struggle for the New Solar Economy*, Berman and O'Connor, 1996, pp. 183-186.

22. Source: IEA web database, member country policies, http://www.iea.org/Textbase/pamsdb/search.aspx?mode=re

23. See *Report of the Photovoltaic (PV) Industry Roadmap Workshop*, Energetics, Inc., Columbia, MD, September 30, 1999.

[2]

Performance Based Incentives for Photovoltaics
Deliverable 1.4: Market Sectors Report

By Sackheim Consulting/Local Power Team
January, 2005

For Sacramento Municipal Utility District
RFP: 40512CJB

Table of Contents

Performance Based Incentives for Photovoltaics
Deliverable 1.4: Market Sectors Report

1. Introduction

Sacramento's Excellent Solar Market Potential
Sacramento has a confluence of elements that make it one of the best places in the US to develop a market for photovoltaics (PV). The region has an outstanding solar resource that is within 15% of the sunniest urban locations in the US, which list includes the desert cities of Las Vegas and Phoenix (1). Hot summers necessitate the widespread use of air conditioners, which means that the solar regime matches electricity demand quite well on a seasonal basis.

Sacramento County also has a large and growing population base of 1,330,711 (2003 estimate). Its vibrant and diverse economy generates $28 billion in regional income, with over $1 billion per year paid for electricity(2). Until 1998, nearly all photovoltaic installations in California were in SMUD's territory. The early local PV market was driven by SMUD owned PV facilities, first at Rancho Seco during the 1980s and then in the first Pioneer program in the 1990s. Later installations have been supported by rebates and some financing assistance for customer owned PV systems.

Three Markets: Residential, Commercial and Public
This report describes the principal market divisions for photovoltaics within SMUD's territory. The residential market has been predominant to date, both in California and for SMUD. This market is characterized by very large numbers of small PV systems, over 900 in Sacramento County, since the solar "Pioneer" programs were set up in the 1990s. It is clear that this market has a huge potential so long as rebates continue to help reduce PV system costs sufficiently, since SMUD has hundreds of thousands of residential customers.

The residential market has been traditionally characterized by people installing PV systems on existing structures. This frequently requires the added time and expense of reroofing. More recently SMUD's program has been redirected toward new homes, where installation costs can be reduced and the need for reroofing eliminated.

Commercial PV systems are usually larger than home systems and frequently can be placed on flat roofs. The combination of scale and a simpler installation environment means that average unit costs per watt of capacity, as well as per kilowatt hour of output, are significantly lower than for the residential sector. In addition, businesses have access to excellent tax benefits that are currently worth more than the rebates.

Large commercial customers usually have lower average electric rates than residential customers, a fact that in the past has led some solar advocates to recommend residential customers as the best market for PV. On the other hand, the large commercial customers are billed on a time of use basis, which enhances the value of PV for them.

Public sector customers are not normally differentiated by SMUD from private sectors ones. They fall into the same general rate classes as businesses with comparable demand. The public sector has access to low interest financing, but pays no taxes so there are no tax benefits available. There are recent laws and policies that urge development of photovoltaics for public buildings, which should increase the market potential for this sector. These same differences between public sector and commercial customers are also characteristic of SMUD itself as a potential public sector investor in photovoltaics.

The Theories of Market Development

The broad theory of PV market development, discussed earlier in the Program and Program Elements Report, is built upon the idea that PV is an expensive way to generate power, but that it is decreasing in cost over time. It further postulates that PV will become competitive in each market when the price falls to a level that nearly matches the cost of electricity for that application. The earliest PV markets are thus targeted at applications where there is no easy access to electricity, such as satellites, remote homes, RVs and boats, etc.

A few models were developed over the years.(3) We have tracked these back to DOE and NASA analyses in the late 1970s and early 1980s. This was picked up by Maycock and Stirewalt in their models where PV comes into direct competition with other sources of power, focusing on PV displacing off-grid power sources and on the transition from off-grid to on-grid applications. In the early 1990s, as grid-connected PV started to grow, the theory of market development was advanced by Don Aitken (and later Don Osborn of SMUD) as the Sustained Orderly Development model. There were a number of important elements in this model that were quite valuable in describing the general development of PV markets. SOD, however, was more than just a model of market sector succession. It was a prescription for action in developing a photovoltaic program. It recommended large bulk purchases to achieve discounts, and PV market goals involving price targets and continuously sustained demand.

According to the development theory, grid-connected residential customers were the next "high value market" after the off-grid market. This should have been followed by commercial, community, grid support and central utility plant. Maycock's and Aitken's models are based on the cost of electricity at each point (i.e., residential electric rates are highest, commercial lower, and utility generation costs the least) and market penetration occurs as the declining price of PV matches the cost level of each market in turn. In the broadest terms, grid connected residential customers were the next major market for PV worldwide, just as the model predicted.

Yet, oddly, the development followed by SMUD was not this path at all, a fact recognized by Dr. Aitken. The first installations at Rancho Seco were utility owned central power plants, which should have been last according to the development models. This was followed by utility owned residential PV, and only later by residential customer owned systems. Commercial applications were placed for the most part on the sidelines, even though they were logically the next step after customer owned PV.

The Role of Rebates in Commercial and Residential PV Markets in California

Since 1998, statewide rebate programs in California have helped create an enormous demand for PV, with over 15,000 systems installed and paid for with the help of grants from the California Energy Commission (CEC) and nearly 1000 more with grants from the California Public Utilities Commission (CPUC).

The CPUC has recently allocated $100 million a year from its Self-Generation Incentive Program (SGIP) to the renewables sector to be used as capacity based rebates, mostly for photovoltaics (4). These are larger grants for commercial customers of the investor owned utilities, and the success shows that the incentive of the rebate is sufficient to generate a large market in California's commercial sector. Oversubscription caused the CPUC to reduce rebate levels for the SGIP from $4.50/watt in 2004 to $3.50 in 2005. Payments in 2006 are expected to drop further to $3.00/watt (5).

Our Deliverable 1.3: Program Elements Report showed how rebate funds for a commercial customer displace potential tax benefits, reducing the incremental benefit to 55% of the rebate value. Thus, a $4.50/watt subsidy for many businesses is worth only $2.48/watt in net benefits. Current average costs for commercial PV systems are between $7.50 and $8.50/watt, depending on systems size. Adding in the long-term financing and O&M expense can bring total costs to over $10/watt, which means the cost of PV is within 25% of where it could be at self supporting, breakeven levels in the commercial sector. PV demand has been stimulated further by electricity rates that have been rising throughout the state.

The fact that the SGIP program was oversubscribed at $4.50/watt shows that commercial demand for PV is quite strong with an incremental benefit of only $2.48/watt in the current market. 2005 will test whether the new reduced incentive levels create as strong a demand as the higher incentive levels. Continued oversubscription in the next two years could indicate that PV is approaching competitive prices even without the help of upfront rebates.

The CEC rebate program limits the size of eligible PV systems to 30 kilowatts and under. Decreasing rebates for these smaller PV systems had a significant impact in the last two years. Application for CEC rebates hovered in the range of 1500 to 1800 in each half year during 2001 and the beginning of 2002, during which time the rebate rose from $2.50 to $4.50/watt. (6) Demand for rebates escalated in the second half of 2002, and peaked at 4603 PV systems in the second half of 2003 in spite of (or perhaps because of) decreasing rebate levels. A turning point came in the first half of 2004 when rebate levels were lowered to $3.20/watt, and demand decreased to 3547 systems, a drop of over 1000 systems/half year. Interestingly enough, while the decrease in demand was focused on PV systems under 10 kw, the number of applications for PV systems in the range of 10-30 kw continued to increase. This disparity is interpreted by the CEC as being the difference between the commercial and residential sectors. The rebate program subscription levels indicate that residential PV needs a rebate level near $4/watt to maintain growth of demand, while commercial PV requires incremental assistance of about $2/watt. The reasons for this difference have to do with the lower installed cost per watt for commercial PV systems and the generous commercial tax benefits.

Value Elements for PV Markets

There appear to be four general areas that drive the market for PV. The first is the net cost of a PV system to a customer and this is strongly affected by rebates, tax incentives and financing arrangements. The value of PV is broadly measured against retail prices for electricity, the perceived risk of continued rate escalation, and the reliability of electricity supply. A third set of concerns have to do with global concerns about the environment, energy supply, and political security. Finally, there are more peripheral (but still significant) values, such as protection of a roof, reducing a building's cooling load, or one's environmental reputation or status in the community. This last group of factors has been shown to be significant in an earlier SMUD study:

> In particular, based on a sampling of telephone interviews, it appears that the value of PV equipment to Pioneer Program participants is much different from the traditional benefits associated with solar power, with people mentioning roof protection or interior heat reduction (shade) rather than the more expected environmental or emission-reduction benefits (7).

This research also showed that local customers strongly rely on the support of SMUD for developing trust in a PV program and helping to make a purchasing decision.

> ...nearly all respondents said they would not participate in the PV Pioneer Program if it were not offered by the electric utility (7).

It is important to consider these factors when evaluating the market for PV in SMUD's territory. The preferences of customers are potentially a great asset to SMUD if they can be mobilized in the right way. SMUD's sponsorship, its role as key PV promoter, and its capacity to assist customers to evaluate and understand PV systems will be critical to the success of a PBI program. SMUD should consider offering a service that provides quick, preliminary PV financial analyses to potentially interested commercial customers using the "Quick Quotes and Market Analysis Tool" computer model from Clean Power Research. (8)

Finally, the fact that PV systems can provide ancillary roof protection benefit can offset the added expense of reroofing. The possibility that PV could contribute to reducing the cooling load of a building should be investigated by SMUD and marketed as a value to the customer. The peak load reduction would also benefit SMUD.

Notes

1) DOE figures show Sacramento with 5.5 kwh/sq. meter/day and Las Vegas and Phoenix with 6.5 kwh/sq. meter/day for a surface oriented due south and tilted at latitude, which means Sacramento has 84.6% of the average annual solar insolation level of Las Vegas and Phoenix. NREL The Solar Radiation Data Manual For Flat-Plate and Concentrating Collectors , found at http://rredc.nrel.gov/solar/
2) Data from US Census Bureau web site, Quickfacts; Electricity data from SMUD annual reports.
3) Paul Maycock in "*A Guide to the Photovoltaic Revolution", Maycock and Stirewalt, Rodale Press, 1985, p. 91*, proposed that PV would first be deployed in remote applications followed by residences and then central power

generation. Don Aitken developed the Sustained Orderly Development and Commercialization (SODC or SOD) for photovoltaics in the early 1990s in a presentation to the State of California, Dr. Aitken most recently brought this model into focus for SMUD in his report: *SMUD PV PROGRAM REVIEW: SMUD'S PV PROGRAM: Past, Present, and Future, FINAL REPORT,* December 30, 2000. Another report on this topic was *Sustained Orderly Development and Commercialization of Grid-Connected Photovoltaics: SMUD as a Case Example, by Donald E. Osborn, Sacramento Municipal Utility District*, Summer 2000.
4) http://www.sce.com/SC3/RebatesandSavings/SelfGenerationProgram/SGIPModificationsfor20052.htm
5) CPUC December 16, 2004 decisions on PV.
6) Data for CEC rebates from *Staff Draft: Pilot Performance-Based Incentive Program Proposal*, CEC, Sept. 2004, p. 4.
7) *SMUD PV Program Review*, December 30, 2000 report, co-authored by Donald Aitken with Warren Schirtzinger of High Tech Strategies, Inc., and Steven Strong of Solar Design Associates, p. vii. Found at: http://www.donaldaitkenassociates.com/resources_daa.html
8) "QuickQuotes and Market Analysis Tool", Dr Tom Hoff, Clean Power Research, presented at the Solar Forum, Anaheim, CA, November 20, 2003

2. SMUD Solar Resource and General Market Assessment

We begin by briefly exploring SMUD's potential for photovoltaic power from a regional scale as a hypothetical but eye-opening exercise. This is followed an analysis of the potential for photovoltaics from economic and physical points of view.

Physical Resource

Sacramento's solar resource is among the best in the United States.(1) With most of the city's annual 193 completely clear days falling between April and October, sunshine is often predictable. This enhances the value of the solar resource significantly.

The SMUD territory encompasses all of Sacramento County and a small part of Placer County, an area of 966 square miles,(2) or 2500 square kilometers. The United States Department of Energy measurement of solar insolation is 2007.5 kilowatt hours annually per square meter for a surface pointing due South,(3) inclined at an angle equal to the latitude (38 degrees, 31 minutes). A flat surface level to the ground has an equivalent annual solar insolation of 1788.5/kwh/sq. meter/year. Multiplying resource times area yields an estimate of 4.5 trillion kilowatt hours of available solar energy over the course of a typical year in the region.

Of course, without some form of storage, this energy is only available during the day, and is much greater, and more predictable in the summer than in the winter.

Regional Electricity Demand

In 2002 SMUD's customers consumed 9,507,444,000 kWh of electric power, a figure that grew at an annual rate of 1% since 1998.(4) It is sobering to note that the sun pours about 470 times this energy upon the SMUD territory in the course of a year.

SMUD's system demand varies by a large factor over a day, season, and year. While the typical base load is fairly stable at 700 to 800 Megawatts year round, the typical peak ranges between a low of 1050 - 1350 Mw from October to April, while a typical peak during the weekdays in July and August varies between 1750 to 2000 Mw. Peak demand averages a ratio of 2.5 to 1 to the base load in the summer. The 2002 annual peak system load was 2779 Megawatts (on July 10th).

Solar production also varies with the seasons, and fortuitously mirrors the seasonal electricity demand, ranging from 2.8 kwh/sq. meter/day in the winter to 7.7 kwh/sq. meter/day for a surface inclined at an angle equal to the latitude.(3) The ratio of the summer to winter solar resource is 2.8 to 1.

Photovoltaic Technology

Photovoltaic cells convert only a fraction of the available solar energy into electricity. Laboratory cells reach efficiencies over 30 percent, and some researchers project that technologies can be developed that convert 40 to 60 percent of the sunlight.(5) Most commercial cells range between 8 and 20 percent, though the panels are less efficient due to the frame size and space between the cells. Several factors further decrease the electricity generated by the panels, such as conversion from DC to AC, losses from the wiring, and voltage mismatch between the PV panels. Solar panels also tend to lose power in the heat of normal operating conditions, and as they age. In addition, there is underperformance due to shading by trees and other obstructions, and non-optimal orientation of the panels.

One could reasonably expect that, given even the best current technology and installation, AC electricity production from photovoltaic systems in Sacramento is typically between 70 and 75 percent of the DC panel rating when they are new. By the end of their 30 expected lives, this might decrease another 15 percent (or more). SMUD’s records of photovoltaic systems show an average performance of 68 percent for existing residential systems. (The installation of new higher efficiency PV systems acts as a system-wide counterbalance to the decrease in performance of older systems.)

The limits to the efficiency of the components of each PV system are a constraint on the ultimate amount of solar resource that can reasonably be tapped. Current technology allows about 10 percent of the available energy from the sun to be converted into usable AC electric current. This still means that there is 45 times the amount of solar energy available in SMUD’s territory when compared to district-wide electricity consumption. Only three percent of Sacramento County would need to be utilized to tap the equivalent of all of its energy from the sun, an area about 30 square miles. This may sound like a lot, but it is in fact not much different than the area currently occupied by local reservoirs for hydroelectric dams. While hydroelectric output varies wildly from year to year, it is worth noting that hydropower only generates between 10 and 30 percent of SMUD’s electricity. Ignoring the intermittent nature of solar energy and the relative economics of hydropower vs. PV, using the same land space for photovoltaics would be more efficient from an energy point of view.

The theoretical maximum role for PV is thus defined in the current power generation regime as the difference between the base load level and the peak. For SMUD this daily variation in demand averages 700 to 1000 megawatts during the summer, and about half this variation from late fall to the spring. This seasonal pattern fits the solar output quite well, with the result that hundreds of megawatts of PV would be a reasonable way to address a significant part of SMUD’s peak demand requirements.

General Economic Parameters

Installation of photovoltaic systems can currently be accomplished at costs between $5 and $12 per watt, depending on a number of factors.(6) SMUD’s residential PV systems range in size from 1 to 4 kilowatts, and cost between $10,000 to $35,000 for grid connected systems. Commercial PV system installed prices can be $1 to $2 per watt cheaper, and thus have the potential to save a lot of money when compared to an equal amount of residential PV.

In past years, SMUD attempted to set a goal of 50 Mw of total installed photovoltaics, which was set aside as “unrealistic.” As the current SMUD fleet of PV systems is already about 1 Mw, this would mean an additional 39 Mw to meet the 50 Mw goal, and would cost about $320 million. Financing over a 15-year period on a 4% interest loan would require annual payments of $26 million. This amount of PV could be expected to generate three quarters of one percent of SMUD’s power. The cost to SMUD would depend on who owns the PV systems, how SMUD would support or subsidize these systems, and how they are financed. We believe that combining the right program elements can bring SMUD’s annual cost down to a realistic level, and provide a PBI package that could be very attractive to PV system owners.

Photovoltaic Markets

The PV industry is currently experiencing extraordinary growth in excess of 30 percent per year. Global production in 2003 was 744 megawatts (7) and will likely surpass 1000 Mw in 2005, and has recently been unable to keep up with demand. This trend has generated an upward price pressure both for PV modules and installed PV systems. Recent price increases have been in the range of 10 - 15%.

The PV market growth has been a direct result of generous support from various governments, especially Germany and Japan. In California, some have questioned whether PV subsidies are “overheating” the market and undermining the longer term goals of the programs. Yet, it is important to point out the important readjustments going on in the PV module industry.

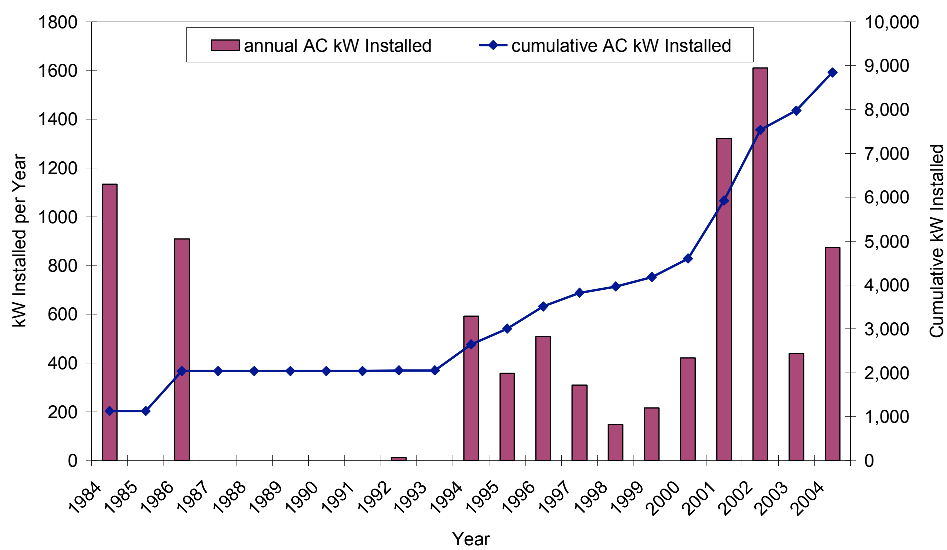
In the past, PV manufacturing was economically a losing proposition for many manufacturers. The recent market growth has created the need for new and more automated production processes which have in turn cut the cost of manufacturing. The result is that for the first time several manufacturers are beginning to break even or turn a profit. The world’s largest PV manufacturer, Sharp, states that they are actually making a profit. Lower manufacturing costs are being achieved and these lower costs eventually will be passed on to the consumer as the capital expense of capacity expansion is paid off.

There are other underlying price improvements in PV systems. The price of installed PV systems has decreased in every sector over the last 7 years. The average cost of CEC rebated photovoltaic installations has decreased from $11.53/watt in 1998 to $8.91/watt in 2004, a remarkable 23% price drop (over 33% when adjusted for inflation).(8)

Presently, the largest PV module manufacturers are adding capacity at a rate that exceeds the current rate of market growth, so it seems likely that production will soon catch up to demand and relieve the upward push on prices. This is tempered by the fact that no one knows what the global level of demand really is, since the demand has recently been constrained by the supply of modules.

Local and state PV markets have been constrained by the availability of rebate funds and have shown the capacity to double demand in less than a year. PV programs and manufacturing are thus the main determining factors for defining demand in the current market. For SMUD the shifts in program structure and direction have caused wild fluctuations as shown in Figure 1 (9):

Figure 1: SMUD Photovoltaic Program Installed Capacity by Year



The last 5 years have seen installed PV capacity double within SMUD's territory from 4.5 to 9 Mw (AC), with 2001 and 2002 being the best years ever at 1.3 and 1.6 Mw respectively. This was followed by a slump in 2003 at just over 400 kw, and a fairly strong recovery in 2004 with the installation rate doubling to over 800 kw. With photovoltaics providing only 0.17% of SMUD's electricity needs, there appears to be an enormous potential for market growth. We believe that a target of 1% of SMUD's electricity coming from photovoltaics within a 10 - 12 year period is a reasonable, practical, easily afforded, and an achievable goal.

Notes:

1) Out of 221 measuring stations in the US, only 33 locations rank higher than Sacramento, and most of these are in low population areas. Measured insolation by Department of Energy monitoring stations in the United States ranges from a low of 922.7 kwh/sq. meter in Juneau, Alaska to a high of 2439.2 in Tonopah, Nevada. See second source in note 3.

2) US Census Bureau, Quick Facts, Sacramento County, http://quickfacts.census.gov/qfd/states/06/06067.html; 1 mile = 1.609 kilometers & 1 sq.. mile = 2.588881 sq. kilometers.

3) NREL, *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*, data for WBAN23232, Sacramento, CA, shows average daily insolation of 5.5 kwh/m^2 for a fixed surface pointing South tilted at latitude, which is equivalent to 2007.5 kwh/m^2/year. Error for this data is given at plus or minus 9%. Publication found at: *http://rredc.nrel.gov/solar/pubs/redbook/.* US Department of Energy publication *Stand-Alone Flat-Plate Photovoltaic Power Systems and Lifecycle Costing Methodologies for Federal Agencies*, gives a higher figure of 5.7 kwh/m^2 for the same location and tilt; table presented in "The Solar Electric Independent Home Book", by New England Solar Electric Inc., revised edition, © 1988, pp. A-26 to A-39.

4) SMUD 2002 Annual Report

5) Dr. Marks claims his patented Lumeloid can achieve at least 60 percent efficiency, while multi-layer wide-spectrum high efficiency cells are expected to reach 40 percent. Top rated premium single crystalline and low production volume commercial cells produced by Sunpower in the San Francisco Bay area are rated about 24 percent efficient in converting sunlight to electricity, while their mass production A210 modules have cells guaranteed to perform at a minimum of 20 percent, and their modules are rated at nearly 17 percent efficient.

6) CPUC and CEC data show most PV systems falling within this range.

7) PV Market Update, Paul Maycock, *First published in Renewable Energy World July-August 2004,* James & James (Science Publishers) Ltd., article found at http://www.jxj.com/magsandj/rew/index.html.

8) Data from Bureau of Labor Statistics shows Consumer Price Index for All Urban Consumers rose from 163 in 2008 to 188.9 in 2004, an increase of 15.9 percent. Dividing the average price each year by 1/100th of the index reveals the price change in fixed 1984 dollars:

year

CPI Avg. PV $/watt

Http://data.bls.gov/PDQ/servlet/SurveyOutputServlet. PV price statistics are from our analysis of CEC data on all PV systems installed under their program: http://www.energy.ca.gov/renewables/emerging_renewables/2005-01-13_ERP_Cmptd_Apprvd.XLS

9) Data and chart of PV installations supplied by SMUD.

3. Residential PV Market

Residential Customer Class: Size and Load Profile

By far the largest number of SMUD customers belongs to the residential market sector: 492,663 in January 2004 or 88.8% of the total. Yet, residential customers in that month consumed 675 million kwh, only 46% of the electricity sold in the district. This increased to 956 million kwh, which was over 53% of SMUD electricity consumption in June, likely the result of increased residential air conditioning loads in the summer.(1)

Individual residential customers on average used 1373 kwh in January, versus 1920 kwh in June. This is equivalent to an average load of 1.8 kw in January and 2.7 kw in June, a summer to winter demand ratio of 1.5 to 1. While this follows the seasonal variation in solar resource (2.5 to 1), residential demand is not as coincident as the commercial demand is with the solar resource profile. Air conditioners and other appliances tend to be turned on (or up) during the late afternoon and early evening. Residential demand peaks between 6 to 7 p.m. from May through September, usually 1 to 1.5 hours before sunset, and takes an additional 1 to 2 hours to drop 100 mw from the peak.(2) To more closely match the PV output profile with the residential demand curve would require tracking PV systems with unobstructed daylight solar access, a combination which cannot reasonably be expected for most residential customers.

The residential rate class is the primary driver for peak demand throughout the year. This peak becomes a double hump (morning and evening) from November through March. In general the residential winter load shape and summer peak timing are less well suited to PV energy than they are for the commercial sector. In this sense there is some mismatch in emphasizing development of PV for residential customers and their demand profile in the SMUD territory.

Residential Rates

One argument for residential PV is that it represents the "highest value market", a term that is not clearly defined in literature we have seen.(3) One assumption of this view is that residential customers pay higher average rates than commercial customers, and thus would be a natural first market target for PV.

Examination of SMUD's rate structures leads to a different picture, where the small commercial sector would— on the basis of rate analysis alone— be the highest value market after the off-grid market as the next market for PV. The following table gives the total customer class bill divided by kilowatt-hours consumed. It incorporates all charges into a "bundled" rate.(1)

Rate Structure Category

Jan. 2004 Jun. 2004

In relation to the cost of photovoltaic electricity, which can run between 20 and 40 cents/kwh (3), the narrow range in SMUD's average electric rates in each sector is actually one of the least significant determining factors of which market should be targeted for a PBI program. While retail electric rates do have significance for the value of PV, they are not the primary determining factor for target market precedence for customers in the Sacramento region.

Cost of Residential Photovoltaics

The justification for categorizing residential customers as the "high value" market disappears when one takes into account the differing cost of PV systems for these markets. The average cost of CEC funded residential sized PV systems (up to 10 kw) decreased from $11.67/watt in 1998 to $8.96/watt in 2004. The following table gives prices of installed CEC rebated PV systems in 2004, broken down by size category. (4)

Residential PV System Size and Average Installed Cost

PV System Size Range low (watts)

The costs for PV electricity from a residential PV retrofit program can be modeled as follows:

1. Output at 1300 kwh/kw/year (Average for SMUD's residential PV systems is about 1400 kwh/kw/year; the lower figure reflects decreased output over time)
2. A system life of 30 years
3. Lifetime output of 30 years x 1300 kwh/kw/year = 39,000 kwh/kw
4. PV systems costing $9000 per kilowatt
5. 15 year tax-deductible home mortgage loan at 6 percent interest

6. Long-term costs of a $2/watt ($1/watt each) for replacement of inverters at the 10th and 20th year with an extended warranty
7. Lifetime O&M costs of $.20/watt
8. PV electricity costs an estimated 38 cents/kwh based on these assumptions.

This figure closely matches other estimates for the cost of PV electricity.(5)

It is also clear from current markets that residential customers are much more willing to pay a premium in cost/kwh for solar energy than are commercial customers. Over the last seven years, 15,000 customers have moved to purchase PV systems under the CEC's rebate program, most of these are under 5 kw and thus very likely to be for residential customers. Even after the rebate they are paying double the average utility rate. Since there is considerable demand stimulated at double the utility rate, we use this as a benchmark target price for residential PV. If utility rates continue to climb, and PV costs continue to drop, then this buy-in level will be reached without the need for any rebate. The following table shows a linear projection for long-term trends in electricity and PV markets. This model assumes a 6% increase in electricity prices, and a 10% decrease in PV system costs, every five years for SMUD's residential market:

*Data analysis from the authors' spreadsheets

This projection extends into the future a trend line that is more conservative than the decrease in installed PV system costs over the last 7 years in California. While these predictions are uncertain, they point to the possibility given these assumptions that PV may no longer need a subsidy from SMUD for its residential customers by 2025. The table provides a general guideline for subsidy level in relation to electricity and PV system costs sufficient to continue the historical demand for PV systems.

The Effect of Residential PV Rebates

The above estimated cost of PV electricity of $0.38/kwh however is not the actual cost of PV electricity to the customer, since the rebate must be deducted. The 2002 CEC rebate reached its historical peak at $4.50/watt and has since decreased to $3.20/watt, a drop of $1.20/watt. During the same period the average cost of PV systems less than 10 kw receiving these grants went from an average of $10.11 to $8.96/watt, a decrease of $1.15/watt. This should have maintained the market, since the target price of PV from the customer's point of view is really the same, an average of about $5.60/watt. But there was instead a dramatic **decrease** in customer interest for PV systems in this price category.

It is likely that for most customers the rebate is the real price cue that they recognize, and that generates residential customer demand. The average actual up-to-date installed cost per watt of PV systems is not readily known, and less understood because the price structure is complex, and contractors are very reluctant to give general pricing information to the public. They do this to gain a market edge on their competition and because site-specific (and other) factors complicate pricing.

At the same time, the hidden character of PV pricing is preventing the public from being fully informed about the economics of PV. Other product pricing can be complex, yet everyone knows what it means if a house costs $350,000, or that gas is $2.50 a gallon. This suggests the need for a different marketing strategy emphasizing pricing that customers can understand, and education of the general public about the economics of PV, in order to stimulate demand and build buyer confidence in their own price judgments. One way to establish prices on a recognizable scale is to provide monthly payments on a loan and equivalent cost per kilowatt-hour. The $5.60/watt net price for PV is equivalent, on the model assumptions, to about 26 cents/kwh. This is double the residential rates of most Californians, and more than double SMUD residential rates. Such a PV price translation may not seem initially attractive to potential residential customers. However, we explore this issue further in the value analysis section of this report.

Residential Market Potential

As of the fall of 2004, there were a total of 1148 PV systems that had been cumulatively installed under SMUD programs over a period of 20 years. (6) We assume that about 1000 of these are residential. This represents a market penetration of 1 out of 500 customers, which suggests that room for growth in the residential market sector is vast by comparison. Personal observations of residential neighborhoods in Sacramento shows that many homes, likely more than half, are not well suited for PV; some have poorly oriented roofs, difficult roofing materials for PV installations (terra cotta tiled roofs in the Mexican style are not uncommon), or roofs that are shaded by trees (Sacramento is noted for its large tree population).

Further reducing the number of available roofs is that many residential customers (about 42%) rent their dwellings. Complexity of billing and ownership arrangements tend to make this residential rental market difficult to penetrate. In addition, commitment to a PV system is a long term arrangement, but mobility is a strong characteristic of the residential rental market. Only 47.5% of Sacramento county residents live at the same residence for five years. (7)

While it may be that homeowners are more likely to remain in the same place than renters, the number of homeowners who move annually is still bound to be quite large. PV systems can be sold with a house, but this can complicate the transaction, and has sometimes resulted in the new owner requiring the removal of the existing PV system.(8) People are also less likely to invest in a PV system if they feel they will not be in the same house to reap the long-term benefits, unless they are convinced that it is an improvement that will enhance the value of their house. The residential market potential for PV could be increased if the value of a PV system could somehow be routinely included in the home resale value.

Economic factors are a key determinant of residential market potential, since PV systems represent a significant expense and would require proof of creditworthiness in order to secure a loan. A large purchase also generally depends on the general feeling that a customer could afford the purchase, and that there are not competing needs or desires that preclude the purchase. In addition to this, there are many customers who simply aren't interested, even though the idea of PV is quite popular. (9) As discussed in the value analysis, there must also be at least some economic justification for most customers to consider purchasing a PV system. If prices are too high, or credit is too expensive and difficult to secure, then even customers interested in PV will not pursue installing a system. Some customers reacted negatively to earlier SMUD loans that carried an interest rate perceived to be too high.

Cumulatively, all these factors are estimated to rule out about 80 to 90% of residential customers as likely prospects for a PV system. Even still, this crude thumbnail analysis suggest a market potential 25 to 50 times what has already been developed in the SMUD service territory.

Alternative Residential PV Markets

Two approaches have been developed to reduce the cost of residential PV as well as the challenges of addressing a diffuse market where many small installations are spread over a wide geographic area. One approach has been to focus on new construction. This eliminates the need and cost of reroofing. This also allows for integration with the design and construction of the house. Modular assemblies can be used in a fairly standardized way, and PV systems can potentially be concentrated into housing developments. PV financing is usually integrated into the home mortgage and adds a relatively small increment to the price of a home. (10) Today it is becoming increasingly popular to design a new PV home so that it is also highly energy efficient. If the electricity consumption is low enough, a small PV system can offset the electric bill, resulting in a so-called "Zero-Energy Home" (ZEH). SMUD is currently working with Premier Homes, a new development project that is building 95 ZEH homes. The PV system equipment supplied by GE Energy (formerly Astropower) will cost $1.5 million, and is expected to produce 300 Mwh annually. This is equivalent to about 200 kw of installed capacity when compared to other SMUD region homes. (11)

As newly constructed homes are frequently in larger developments, the landscaping, orientation of roofs and PV modules can more easily be integrated into an efficient PV design. Considering all these factors along with an attractive financing package would result in a much larger fraction of owners of new homes as a potential PV market than existing home owners. New home sales in Sacramento's metropolitan region was reported to be 9530 (about 25% of these are outside the county) (12), a figure which has tripled over the last 15 years. This new housing market provides a unique opportunity for PV development.

The Deliverable 1.3 report discussed two community solar projects, in Pennsylvania and Arizona that allowed customers to buy shares in a large PV system. This collective arrangement reduced the cost of PV compared to a residential roof top systems. This approach also has the potential to free customers from the constraints around property ownership, rental or transfer. It also bypasses problems such as the expense of reroofing, lack of adequate roof space, shading, aesthetic concerns, and poor orientation of the roof. If the program is flexibly designed, customers could buy and sell shares in a wide range of PV capacity or energy denominations, and carry the ownership with them wherever they moved. Credit for the PV power generation would be constrained to Sacramento county, but trading arrangements could be made with other areas of the country if the idea spread. A community PV system could be installed on a shared rooftop, such as a large commercial facility that already was interested in PV. The added benefit could be a larger system than the business would otherwise have wished to purchase, reducing the cost/watt for both the business and participating residential customers. The PV electricity would be consumed on or adjacent to the business location, but the financial benefits would accrue to all the owners. Essentially, one customer would be selling electricity to the other, but it would be set up as a form of retail wheeling.

Notes:

1) From Sacramento Municipal Utility District Monthly Sales Data by Rate Schedule spreadsheets, as of January and as of June, 2004.

2) Source of demand analysis is the *2002 Class Load Study, Sacramento Municipal Utility District*, December 30, 2003. The 100 Mw figure is arbitrarily chosen, and represents just the highest tip of the daily peak for residential customers. The duration of demand remaining within this range of peak varied from 5.5 hours in May to about 3 hours in June through August.

3) Table 1 & Table 5, California Energy Commission, ***Comparative Cost of California Central station Electricity Generation Technologies***, Staff Report, publication # 100-03-001, August 2003, pp. 3 & 11. gives levelized cost of PV at 42.7 cents/kwh. Summary data found at http://www.energy.ca.gov/electricity/levelized_cost.html The assumptions by which they arrive at this figure are suspect, as they model only a 20 year economic lifetime, when it should be 30. This error is offset by the higher cost of home PV, as their model purports to be for utility central generation. The Solar Electricity Price Index, produced by Solarbuzz Inc., can be found at http://www.solarbuzz.com/SolarPrices.htm.

4) Our analysis of data from the California Energy Commission excel spreadsheet: http://www.energy.ca.gov/renewables/emerging_renewables/2005-01-13_ERP_Cmptd_Apprvd.XLS

5) see note 3.

6) California Energy Commission spreadsheet *2004-10-15_GRID_PV.xls*.

7) US Census Bureau, 2000 Census looked at residents over 5 years of age who lived in the same place in 1995 as in 2000. Http://quickfacts.census.gov/qfd

8) Evidence of this was SMUD's recent (and first) auction of 150 kw of PV modules removed from the sites of Pioneer program customers. Change of ownership was mentioned as one cause of removal. Phone conversation Caesar Beltran, Oct. 2004.

9) A 2001 national poll asked respondents if they supported research and development of new energy technologies such as solar energy, and over 90% answered in the affirmative. The $100 million solar bond measure in San Francisco, Proposition B, garnered about 75% of the vote in 2001, while Local Power's Solar H-Bond measure got 56% support in the same election.

10) Assuming a $350,000 new home, which is in the average range in Sacramento, a 2 kw system costing $18,000 with a $4.50/watt rebate would result in an additional $9,000 on the mortgage, or 2.5%.

11) *GE Energy's Solar Systems Reduce Electric Bills in Sacramento's First Zero Energy Homes Community*, November 30, 2004. http://www.solarbuzz.com/News/NewsNAPR444.htm

12) *Sacramento New Home Sales - December, 2004*; Building Industry Association of Superior California (BIA). http://www.biasup.org/sales.html

4. Commercial Customer PV Market

There is no question that commercial customers have the potential to offer an excellent market for photovoltaic power. Three rate paying classes form the most important sectors to consider, the most promising being the large industrial/commercial GUS-S rate. This rate is metered under Time-of-Use, and is mandatory for all customers with peak demand between 300 and 499 kilowatts for any three consecutive months, and optional for customers with peak demand less than 300 kilowatts. As of January 2004, there were 591 such customers. In that month GUS-S customers collectively purchased over 87 million kwh of electricity with an average demand around 200 kilowatts.

Assuming PV system sizes are constrained by the average demand at the site where they are installed, then the total potential market for PV within the GUS-S rate customers would be about 120 Megawatts of AC power, or 160 Mw peak DC. A market penetration of 7 percent, about 36 customers, would mean installing 10 Megawatts of PV power at an average system size of 280 kilowatts (dc peak). Such systems would require about 28,000 sq. feet (assuming 100 sq. ft/kw installed). This would occupy a rectangular roof area 100 by 280 feet. Large commercial rooftops, such as a shopping mall, factory, or a large office complex could support such a system. Some commercial facilities also have other suitable areas, such as parking areas, undeveloped land, etc., which could even prove superior to a rooftop assembly, as it could allow for cooler operation, lower cost installation, and opens the possibility for using solar trackers.

Rate structure of GUS-S customers

SMUD has low kwh energy charges for large commercial customers that create a difficult prospect for competition from photovoltaic energy. For most of the hours of the year these rates range between 5.5 and 7.5 cents/kwh. Fortunately for PV, a number of factors significantly increase the cost of this electricity from these basic rates, including: demand and service charges, the premium cost of peak power during the day, the six percent increase in all rates announced for 2005, and local taxes on electricity. In addition, the economics of photovoltaics should take into account future expected escalation in retail electricity prices.

Demand and Service Charges

In addition to the basic $85 billed each month per meter, a charge is placed on peak demand that can add thousands of dollars on top of the kilowatt-hour rate energy charge. If these are folded into the kilowatt hour rate, then average rates were 8.2 cents/kwh in June and 7.5 cents/kwh in January, 2004.

Time of Use Premium

Time of use (TOU) rates place a large premium on summer peak power, which is significant for photovoltaics. On weekdays between 2 p.m. and 8 p.m. TOU customers pay a super-peak rate of 14.744 cents/kwh, and for two hours on either side of this (12 p.m. to 2 p.m. and 8 p.m. to 10 p.m.) pay a lower peak rate of 9.749 cents/kwh. At other times of the day, and all day on weekends and holidays, an off-peak rate is charged of 7.539 cents/kwh. Winter rates are: 7.158 cents/kwh for peak power (weekdays, noon to 10 p.m.) and 5.471 cents/kwh for all other hours.

Peak TOU rates imply that the real value of photovoltaics, if measured by the value of delivered electricity for the customer, is higher than the average retail rate. This enhanced TOU value for PV is moderated somewhat by the exclusion of weekends, holidays and all morning hours. The enhanced TOU value for PV is also reduced significantly by SMUD's short summer billing season, which is two months less than that of all the major electric utilities in California. Furthermore, if solar panels are oriented more to the West, the impact of starting peak rates at noon can be offset somewhat, but the other factors cannot. The enhanced TOU value of PV can be significantly higher than average retail rates.

2005 Rate Increase

SMUD has announced a 6% rate increase, expected some time this year. This will raise the effective average rates for the GUS-S customers about ½ cent/kwh, thus increasing the value of energy that PV can displace.

Small Commercial Rate Classes

While smaller commercial sized PV systems are a bit more costly, this can be made up for by the higher rates charged to small commercial customers. We have seen how they have the highest average total rates, about 10.1 cents/kwh. This will jump to 10.7 cents/kwh later in 2005 (11 or more once taxes are included). These customers have the same tax benefits as the large commercial customers and a similar demand profile. They also numbered 46,267 customers as of June, 2004.

Taxes

Sacramento County residents pay a 2.5% tax on their electricity purchases, while those who live in the city of Sacramento pay 7.5%, and appear to be excluded from the county tax. Avoiding paying this tax on electricity displaced by PV is another value of PV to SMUD customers.

Net Effect on the Current and Future Delivered Value of PV

The net effect of all the above factors is that PV power in 2005 can be valued at between 9.5 and 10.5 cents/kwh for SMUD's Time of Use customers. If we assume a 1 percent annual increase in the cost of electricity over the 30 year assumed life of photovoltaic systems, then the value of PV to the customer should be estimated on the basis 11 cents per kilowatt hour during this period.

Cost of Photovoltaic Systems

Commercial facilities offer several advantages over the type of residential PV installations that have been customary in SMUD's earlier programs and in California generally. Residential installations, are typically in the range of 1 to 4 kilowatts, and retrofits of existing homes average between $9.00 and $9.50 per watt installed. Large commercial installations can be installed between $7.50 and $8.50 per watt. In other words, simply choosing to target a PBI program at large commercial installations is worth the equivalent of $1 to $2 per watt in reduced cost for photovoltaic systems. This differential represents a major fraction of typical rebates given to small home installations, only *this $1 to $2 per watt savings would cost SMUD nothing.*

Another commercial customer advantage is that businesses can take large Federal and California tax deductions that are unavailable to residential customers. These combined tax deductions amount to 45 percent of the cost of the PV system. For a PV system costing $7.50 per watt, this deduction is worth another $3.37 per watt, which is much larger than SMUD's existing commercial rebate of $2/watt.

By targeting PBI funding to the large commercial market sector instead of the residential program, SMUD can realize a benefit worth between $5 and $6 per watt, without any SMUD rebate money being paid, and with commercial customers realizing a potential net installed cost between $4.10 and $4.65 per watt.

It is important to realize that commercial rebates displace tax incentives, which reduces their incremental value. By incremental value we mean the extra benefit a business receives by getting the rebate with a partial tax write-off versus getting no rebate and a full write-off. Since the tax benefit is calculated as a percentage of the installed cost *less the rebate*, the rebate actually decreases the tax write-off. Here is a table with parallel cases; both pay the same price for the PV system, only one receives a standard $2/watt SMUD rebate while the other does not.

Net benefit of rebate	**$27,500**	

The net value of the rebate is only $1.10/watt, which means that $22,500 in rebate money was effectively lost in helping the federal government collect more taxes.

On top of the net costs must be added the cost over a 30 year PV system life for replacing the inverter, financing, and O&M. These collectively can add up to $3 per watt over the long term and should be taken into account.

The table below gives a projection model for the commercial sector, with PV system costs and tax benefits for large commercial customers. Note that the net subsidy benefit is a little more than half the full real subsidy needed to accomplish this rate under the current buydown regime, which is an important reason why the buy-down approach needs to change. The PV electricity cost figures assume a SMUD low interest loan at 4% interest rate. Electricity prices do not account for the effect of rate increases after the purchase a PV system.

* analysis from the authors' spreadsheets on PV prices and cost of PV electricity.

Performance of Commercial PV Systems
This model serves as an example of how a commercial PV system might perform. SMUD territory PV systems currently average annually about 1400 kwh per kilowatt of installed modules, or 42,000 kwh/kw of PV energy produced over a 30 year assumed system life. Adjusting for an expected 20 percent degradation in output by the end of the 30 year life and assuming a linear degradation, this results in a 30 year total PV production of 37,800kwh/kw. Our assumed figures above estimate the total installed cost of one kilowatt of PV between $6.50 and $7.50 per watt, after tax credits and deductions. The net cost per kilowatt hour is thus $0.17 to $0.20 based on these assumptions, about double the price of delivered electricity, reduced from a gross cost about $0.27/kwh for a large commercial PV system, and $.35/kwh and up for a residential PV system. If the average PV system performance can be improved from 1400 kwh/kw to 1600 kwh/kw, the net cost of PV energy is reduced by 14%.

Program Elements
We have shown how the scale and tax benefits can drive the price of PV power down by about one-half. Key program elements can achieve even further reductions in cost. Potentially the most valuable of these is the low- or zero-interest loan. This has been critical to the success of the German Feed-in Tariff, which now provides government funds at 1.8% interest. Interest of 5.5 percent over a 10 year period can add more than 25 percent over the purchase cost. The fact that PV is paid for mostly upfront already gives it an inherent disadvantage over fuel based systems. Any way that can be devised to cut the impact of this upfront cost will tend to bring the cost of PV into balance with other power sources. With this advantage, PV power can approach parity with the long-term price of delivered power. The resulting PBI incentive premium, paid on a kwh basis could then be correspondingly quite low.

5. Public Sector PV Market

As mentioned in the introduction, the public sector is not given separate status as a customer billing class, except for light rail which is aggregated with street lights and agriculture. This customer class has its highest demand at night and drops during the day, counterbalancing the load from other sectors. Even still this customer class would be a potential candidate for PV, as light rail has a significant demand during the afternoon, has a large amount of land and uses DC current, a natural fit for photovoltaics.

Sacramento is the state capitol, and as a result has a large government presence. These include the various government agencies that are located here. Some of these agencies already have a significant relationship to photovoltaic power, such as the California Department of Transportation (CALTRANS), CAL-EPA, and the California Energy Commission. The state has mandated that government agencies place a priority on putting up PV systems for their facilities, though no money has been budgeted for this purpose.

Education has a large local presence, with over 30 thousand employees (1), most of them in the public sector. This represents about 5% of the county's employment. These include grade and high schools as well as community colleges and California State University Sacramento (CSUS). Schools often have large buildings with flat roofs and excellent solar access as well as large open yards and parking areas. CSUS occupies over 300 acres and has nearly 28,000 students. (2)

Another public sector customer that has large roof and parking areas and numerous facilities is the US Postal Service. One of the largest PV systems in the Sacramento region is being built at the West Sacramento Post Office. (3) The 403 kilowatt system will cover 28,000 square feet, providing shading for parking. The $6.3 million project includes energy saving features. These savings, together with a $1.6 million rebate is expected to cover the full cost of the entire project. The postal service says that no money will come out of their capital budget. This is an excellent example of how to fund a public sector project and make PV affordable.

While the public sector lacks the leverage of tax credits, it does have bond authority and access to low interest capital. In addition, many government facilities have large on-site electricity demands. Public sector facilities in SMUD's territory are also eligible for funds from the CPUC's SGIP, which is administered in this region though PG&E, and is currently worth $3.50/watt. Because SMUD's public sector customers do not pay taxes, the rebate money carries no loss of tax benefits as it does for the commercial sector. This combination makes the public sector an excellent candidate for lower cost PV systems.

It should be noted that current CPUC rules exclude any PBI program from contributing to a project funded by an SGIP rebate. As the public sector is most benefited by the rebate, and these funds are not drawn from SMUD's PV program, funding public sector PV with SGIP rebates appear to be the best option under the current rule regime. The CPUC is soliciting rule changes to its program with the aim of reducing its rebates and eventually phasing them out. We recommend that SMUD propose a cooperative strategy with the CPUC rather than the current exclusive one as an excellent "decrease the rebate and exit strategy". A cooperative program would be especially beneficial for public sector customers, who could accept a lower rebate together with a modest PBI payment.

Finally, SMUD itself is a public sector agency with many of the same characteristics as its public sector customers. It has the added advantage of being able to set the rules for PV systems in its territory and coordinating financing internally. For this reason it is perhaps not surprising that nearly 6 mw of the total of nearly 9 mw (AC) of PV installed in SMUD's territory are owned by SMUD.(4)

Notes:

1) Most recent data from 1999, http://www.sacog.org/demographics/employment/rads/sacr.cfm
2) http://www.csus.edu/pa/quickfacts/facts.html
3) U.S. Postal Service Brings Energy Efficiency, Solar Power to Northern California Processing Facility, October 13, 2004, http://www.solarbuzz.com/News/NewsNAPR426.htm.
4) Communication from Stephen Frantz to Robert Freehling, *Answers to RF Query.doc*, Jan. 9, 2005.

6. Value Elements for PV Markets

There are three players on the purchasing end of the market for PV that must accommodate their various interests. These are: the buyer, the utility (SMUD), and the rebate authority (SMUD again, but possibly also PG&E's SGIP program). Optimizing a PBI program means optimizing the value components for those who are in each of these three roles. This value analysis will consider how value can be gained and utilized by each of these players, and then further enhanced by incorporating program elements that have been discussed in this and earlier reports.

A. PV Value Elements for the Customer

Average Delivered Electric Rates
Average electric rates represent the foundation for the value of delivered electricity. As shown above, these ranged between 8.3 and 10.2 cents/kwh, depending on the customer class. Actual rates are further broken down into nearly 200 rate classes divided between the different types of customers. Most of these rate classes are residential, and many range between zero and just a few customers in each class. The rates in each of these smaller classes fall into a much wider range than the general customer class rates. Since SMUD does not generate a profit, one can assume that the average rates reflect the general cost of providing electricity to its customers.

Customer Peak and High Tier Rates
Photovoltaics produce a significant portion of electricity during times of peak billing rates. This has the largest significance for customers who have Time of Use billing. While Time of Use customers have set rates in each time block (high peak, peak and off-peak), each customer will use their electricity at different times of the day and year. This creates an "effective rate" calculated by simply dividing the total bill by the number of kilowatt hours, which can vary greatly. For customers who buy a lot of electricity "on peak", their bill rates can be 1 to 10 cents/kwh higher than the average for their rate class. In addition, PV power produces much of its annual output specifically during the peak hours, and thus has some value benefits from peak pricing that are irrespective of the customer's load profile.

Future Electricity Price Escalation
Flat electricity prices during the 1990s lulled many people into assuming that electricity would grow cheaper over time, particularly with the advent of deregulated markets. An historical view, however, shows that over a longer time frame electricity prices do indeed rise, and in fact have doubled since 1978. The longer term trend has been confirmed again, as national electricity prices have risen about 10 percent since 2000.(1)

Roof Protection and Cooling
It is doubtful whether this is in fact a real net financial gain for the customer, but it likely offsets the expense of reroofing in many cases. In addition, it is certainly something that many customers value, and so should be taken into account and given a value. This may require some research to establish.

SMUD's Good Name

Another factor in the value equation not to be underestimated is the potential value of SMUD to its customers. The informal customer survey carried out for Dr. Aitken's report (mentioned above), showed that they would not have purchased PV systems if it had not been a program of SMUD's. SMUD provides a source of trust, information and assurance of benefit to purchasers of PV systems. This can manifest as an actual financial benefit to the customer as well. A business that wants an evaluation of the effects of buying a PV system on their taxes, electric bill and bottom line could have to pay an accounting firm a sizable sum of money. SMUD can save them this expense and remove significant market barriers for many businesses.

SMUD Low Interest Loans

While residential customers have access to long-term mortgage loans which have tax deductible interest, commercial customers are in a different position. Borrowing rates are substantially higher than what is available to SMUD, a fact that is worth millions of dollars to their solar program. Simply passing along the low interest rate would cost SMUD nothing and provide a huge boost to the PV program. A PBI program that paid against the interest would also eliminate the problem of potential taxation of the PBI payments. The savings would be passed along to the commercial customer in the form of a lower interest rate, making the PBI payments disappear (or mostly disappear) from their books.

B. Value Factors for PV Program Funds

Giving Higher Value to Rebate Payments

Current PV program funds that are used for commercial rebates can be diverted to a much more productive use of funds. The existing tax policies can better serve for the initial incentive, while the rebate funds can be used to promote performance, long term operation and maintenance, and loan financing. In addition, commercial customers save money by installing larger PV systems. We have shown how, without a penny of program funds, commercial PV system installed costs can average below $5/watt, and potentially come close to meeting the program target of $4/watt.

Paying Over Time

A PBI program has the benefit of distributing its payments over a number of years. If the time frame is stretched out long enough, further benefits accrue to SMUD's PV program. We have already mentioned that electricity prices escalate over the long term. This fact can be used to leverage marketing benefits for a PBI. In addition, a long term payout will help avoid budget crunches if the PV program continues to escalate its budget at a rate faster than inflation. Adding just a few percent to the growth rate can have dramatic effects in the long term vis-à-vis the ability to make sustainable larger annual additions of PV.

C. SMUD Power Purchase Value

The greatest impediment for power purchasers buying PV electricity is the perceived high price. Part of a successful PV program should, in our view, involve power purchase planning and input. The PV program can approach them with a good deal for all concerned. PV electricity should have some real value to SMUD power purchasers: much less than the usual expected price of 15 to 40 cent/kwh, but also more than zero. If the power purchase department would pay for PV at base-load rates, then it would be possible to create an attractive financing package for customers, and leverage expansion of the PV program.

This payment would not be a power purchase, but would be compensation for the stacked benefits of:

1. The value of fulfilling the RPS kwh purchases, which amounts to a Green Tag market where the environmental and financial benefits are local
2. The net incremental value of distributed power to SMUD
3. The benefit of reliable power during peak hour in summer

Green-Tags: The RPS Value of Renewables

Electricity generated from renewable energy sources is typically sold at a premium relative to "conventional" electricity. Thus, the fulfilling of an RPS requirement comes at a premium relative to electricity from natural gas, coal or fuel oil generators. This premium is stripped off from electricity generated from renewable energy sources and sold separately as a "Green Tag" which has legal status as a contract for ownership of the environmental value of the renewable. This allows a retail purchaser to cover the excess cost of the renewable electricity, while another customer pays for only the stripped or "null" electricity. This electricity stripped of its "green" attribute sells at the same price as conventional sources. A utility, on the other hand, buys these attributes in bulk and can receive credit for its renewable portfolio. The cost varies depending on whether it is a bulk or retail purchase. Retail green tags can sell for $20 to $40/mwh for most renewable electricity sources, and at a higher rate, $20 to $200/mwh for premium solar tags. (2) Discounts for bulk purchases can lower the cost. The money collected goes directly to the generator, with a profit taken by the selling agency.

The Green Tag value of customer-owned PV is not currently compensated on a kilowatt-hour basis by SMUD. Here is a table of the 30 year value of PV green tags per watt of installed capacity (DC), assuming an output of 1400kwh/kw/yr (or 42 kwh/watt):

Distributed Generation

There is a definite value to SMUD for having a local distributed form of generation. This value, both for Southern California and SMUD specifically, has been estimated in recent reports. (3)

Peak Power Supply

Wholesale peak power in the summer can be very expensive; avoiding the cost of the most expensive electricity supplies is definitely of value to SMUD. In addition, the costs of transmission and distribution, along with line losses, at these times can be particularly high. Local PV supplies power at just the times when it is most needed, avoiding congestion, overload of substations, and lowering the risk of power failures.

Notes

1) Bureau of Labor Statistics, Consumer Price Index for Electricity. http://data.bls.gov/cgi-bin/surveymost
2) Internet resources on Green Tags include: The Bonneville Environmental Foundation, which created Green Tags, and has a Green Tag website: https://www.greentagsusa.org/GreenTags/index.cfm, and Environmental Media Services, http://www.ems.org/renewables/green_tags.html; Prices for Solar Green Tags were given in Tom Starrs presentation What is a 'Green Tag' Anyway?, at the CSC Solar Forum in San Francisco, May 5, 2004.
3) Particularly, Tom Hoff's report to the SMUD board on the value of distributed generation, in 2002.

7) Conclusion

The market potential for photovoltaics is defined by a number of parameters. In general, the current cost of PV on the open market is too high to generate significant demand. For this reason governments have established support programs to promote and incentivize a technology that fulfills public goals such as global security, local availability of power supply, and environmental protection. Photovoltaics taps a vast energy source larger by orders of magnitude than all the fuels on earth, and a resource that is not depleted by our use of it..

The general public values these and other attributes of PV, including its ability to protect a roof and help reduce the cooling load of a building in the hot summers. Many purchasers of PV systems enjoy the elegant simplicity and high technology that allows one to place a flat crystal in the sun and quietly get their own personal energy supply from it. In this sense it appeals to the desire for individuals to meet their own needs without reliance on forces outside their control. A similar motive drives many people to pay a premium for solar electricity just so they don't have to pay a bill to the utility. At the same time, market research has shown that most Americans are willing to pay extra for a product that is environmentally beneficial.

From the largest perspective, the principal barrier to using this almost unlimited (from a human perspective) energy source is its cost. The raw resources from which PV modules are made is not scarce, the most important of these, silicon, is the most abundant and universally available solid material in the earth's crust. The technology upon which the production of PV modules is based has been continuously improving for half a century, raising efficiency and lowering the costs.

There is no reason to expect that this cycle is nearing its limit. On the contrary, current innovations are pushing the envelope even further. Improvements in manufacturing and installations have continued over the last seven years, resulting in global and regional reductions in cost. These have defied the predictions of many that PV was about as cheap as it was going to get: nominal costs of PV installations in California have dropped 23 percent since 1998. At the same time, US electricity prices have increased 10 percent.

Standard economic development theories for PV hold that each market will be penetrated as the cost of PV draws near to the current cost of delivered electricity. This theory carries the caveat that financing costs and cash flow must also be taken in account. Nevertheless, by the time PV reaches parity with delivered electricity rates, it will already carry a significant premium value. These premiums are the same factors that currently drive people to purchase PV systems: expectation of future increases in electricity costs, high cost for peak power, reducing the cooling load of a building, self-reliance, environmental values, etc.

Residential PV Markets

Thousands of California residential customers, and hundreds in SMUD's territory, have moved to purchase PV systems with the help of rebate programs. Even after the rebate they are paying double the average utility rate, which seems to define the buy-in level for residential PV. At some point increasing utility rates and decreasing PV costs will grow close enough that a significant subsidy will not be necessary. We broadly predict that this should happen in the next twenty years.

There is a gross market potential (in 2004) of about 500,000 homes, of which we roughly estimate 80% to 90% would not be likely candidates due to poor conditions for PV, exclusion for rental units and highly mobile customers. 6000 new homes per year are sold in Sacramento County, and these represent a rapidly expanding market, having tripled since the early 1990s. New homes make much better candidates for PV, as they can be incorporated into the house and landscape design, reroofing is not necessary, and the PV system can be incorporated into the existing financing.

PV systems, especially after rebates, are likely to add between 1% to 3% to the cost of a house This is similar to (or less than) other price impacts that are normal in this market, such as annual increases in housing prices, closing costs, points on a loan, and property taxes. And the customer will receive definite long term value from this extra cost. For this reason, we assume the new home market is almost entirely an open field for PV. As residential PV systems average 2 to 4 kilowatts, the total installed capacity potential would be 100 to 400 Mw, with an added 12 to 24 Mw each year, under the above market assumptions. If the constraints coming from rentals and a mobile population are lifted by a creative program design, then the ultimate residential market potential could be up to ten times larger.

Commercial PV Markets

After cultivating a residential PV market for over a decade, we believe that the commercial PV market stands as the next great market venue. Lower installed system costs and better performance reduce the average price of PV generated electricity 10% to 20%, relative to residential systems. Business customers receive a large tax benefit worth a further 45% of the cost of the PV system. These two effects can be enhanced with SMUD providing low interest financing for PV systems. While still in the early development stage, signs are emerging that commercial PV is approaching a viable market.

The remaining gap between average electricity price and PV electricity cost for the commercial sector can be closed a variety of elements that need to be carefully measured and given real value. The elements include the elevated value of PV during peak demand hours, as well the avoided costs of due to the stacked benefits of renewable energy and distributed power sources.

The proper attribution of where these value elements lie, and who benefits by them, is critical for success in a PV program. Peak benefits will go to different parties, depending on the rate structure. For example, small commercial customers have the highest average rates, but their flat rate structure creates a cost for the SMUD power purchaser during peak hours that must be recouped elsewhere. This transfer of cost is more acute for SMUD than for other utilities, since small business customers who use more electricity actually pay a lower, not a higher, rate.

The large commercial customer is on time of use billing, which raises the value of PV power on-site for the customer significantly beyond that listed in the table. Projected billing tables for 2005 show the 926 customers in these classes paying an effective full bundled rate (including demand and other charges) that begins at 7.4 cents/kwh. The upper limit is not clear, but 100 customers appear to be paying over 12.5 cents/kwh. It can be assumed that PV electricity over the course of the year would be valued well above average TOU rates, assuming proper orientation of the modules. A more accurate accounting of PV electricity value needs to be determined by further modeling.

The gross commercial market is defined by commercial demand levels, particularly demand levels that are coincident with the system peak load profile. Average demand for time of use customers is 230 Mw, while their non-coincident aggregate peak is 538 Mw. Typical summer peak demand for all commercial classes is between 750 and 850 Mw. These fall within range of the difference between total peak and base load, and thus represent a value for PV to SMUD.

Public Sector customers fall broadly within the commercial rate class, and are incorporated in the commercial demand profile, but they lack the tax benefits available to commercial customers. For this reason, PV in the public sector comes at a cost significantly higher than commercially owned PV. We recommend at this time that funds for support of public sector PV be drawn from the existing buydown funds of the SGIP until policies can be changed that open up cooperation between the CPUC and other PV programs.