The Economics of Solar Energy for California

A White Paper

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Draft

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1. Executive Summary

The purpose of this White Paper is to assist the Governor's office in developing the Million Solar Systems initiative. This initiative seeks to achieve tangible economic, energy and environmental benefits to the state by stimulating the installation of one million solar systems within ten years.

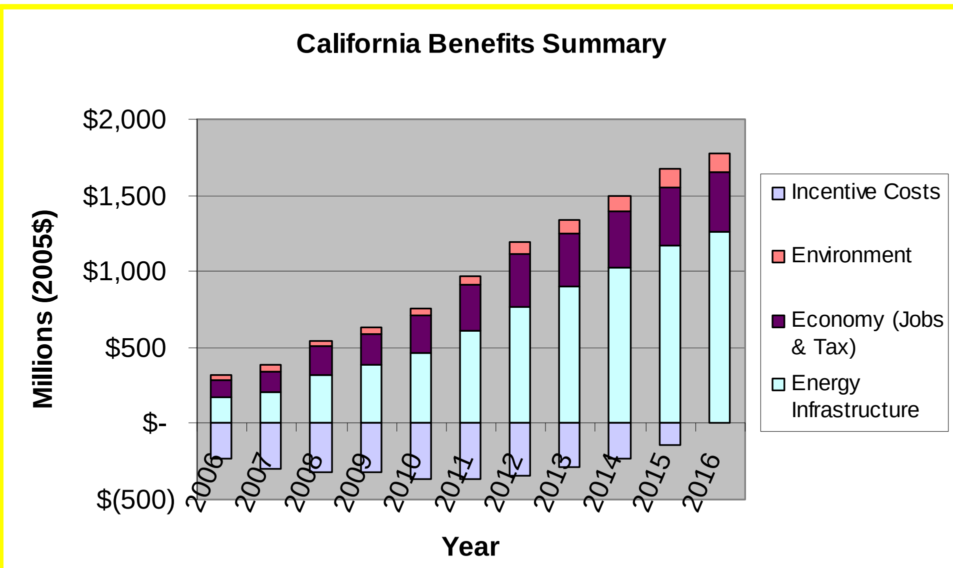
Benefits to California from the Million Solar Systems initiative are substantial, totaling $6.4 billion *net of incentives* by the end of 2015, not including direct customer energy savings.

- $6.0 Billion Energy Infrastructure Savings
- $0.66 Billion Environmental Savings
- $2.6 Billion Economic Savings
- $2.9 Billion Incentive Costs

- $6.4 Billion Net Savings to California

- $9.6 Billion Direct Customer Energy Savings
- 3,247 Megawatts of Installed Solar Electric Capacity
- 273 Million Therms of Installed Solar Thermal Capacity

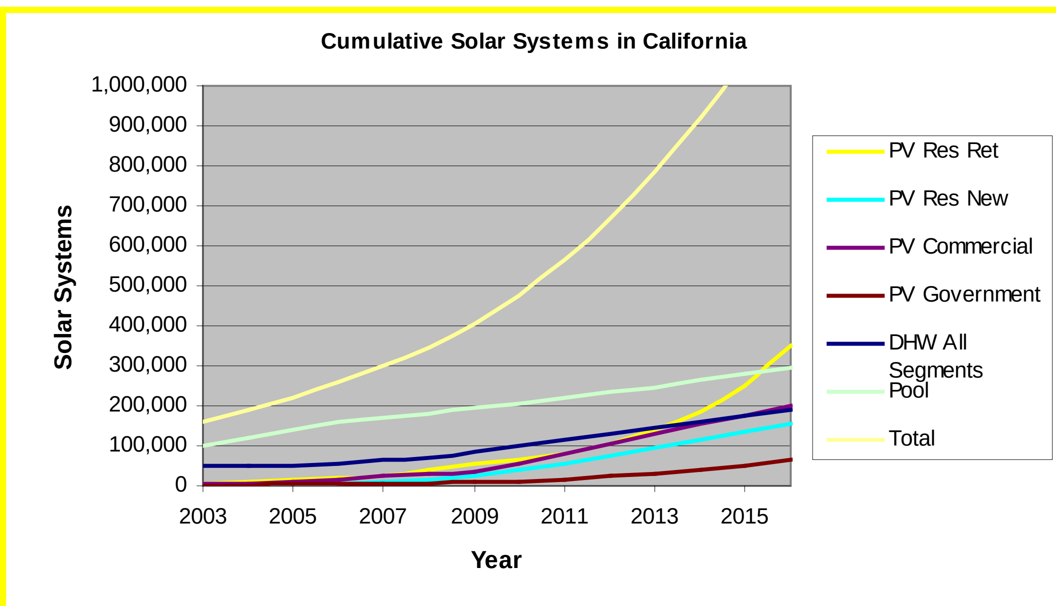
The total benefits to California are dependent on the number of solar systems installed -- which is directly affected by the incentive funding necessary to generate this level of demand. The Million Solar Systems initiative is indeed achievable within ten years, with the level of incentive funding set in each solar market segment to maintain the necessary overall market growth rates. As shown in the chart below, the contributions to California's energy infrastructure, environment and economy will be substantial and will continue to grow even after the program's goals are complete.



Customer economic behavior drives the solar market. Therefore, all policy and regulatory programs must be evaluated in terms of how they affect customer behavior and market segment growth. ***Assuming a level of incentives that do not take into account actual customerpurchasing behavior based on net customer economics (primarily expressed in the demand curve) will almost definitely result in fewer systems being installed within the ten-year timeframe.***

Since the solar market is composed of multiple market segments (residential, commercial, government, new construction) and multiple technologies (solar electric and solar thermal), a modeling tool is needed that encompasses all these segments using a consistent set of assumptions and data. The *Million Solar Systems Model* provides a framework to evaluate the benefits and costs of solar energy in the context of customer behavior. This model is based on detailed analyses of solar market data from the California Energy Commission and California Public Utilities Commission, as well as similar data from the New Jersey Clean Energy Program, Hawaii Solar Program, Japanese Solar Program, and Germany Solar Program. Energy infrastructure and environmental savings were based on the E3 Avoided Cost model. Customer behavior and economic savings are modeled based on research done at Berkeley, Stanford and Princeton. This is a “work in process” since additional market data should be incorporated as it becomes available to increase the predictive accuracy of the model.

We recommend that the Million Solar Systems Initiative consider all applicable distributed generation solar technologies, including both solar electric and solar thermal. Providing customers with a choice of technology will facilitate their buying decision and allow systems to be installed in a wider range of applications – particularly where roof space is constrained. In addition, as shown in the graph of cumulative systems below, these thermal technologies will account for roughly 50% of the entire million systems – reducing the amount of incentive funding required for the program as a whole



Based on the results of this work we have the following recommendations:

- Structure incentives and related public policy to drive customer purchases based on actual market conditions and accurate historical data. Note that the overall amount of incentive funding may be greater than previous plans and studies because the goal of one million solar systems is ambitious. Nevertheless, the benefits to the state are commensurately greater and will do more to alleviate our short-term energy shortages.

- Establish predictable, consistent incentives that change with variations in life cycle costs, third party incentives (including RECs) and energy prices. Existing CEC and SelfGen programs have been effective to date. In addition, we recommend a public relations campaign – similar to the Flex Your Power campaign – to further stimulate customer awareness of the favorable economics for solar.

- Use an analytical tool such as the *Million Solar Systems Model* to fully evaluate solar net benefits and costs in the context of real-world customer behavior

California is blessed with abundant solar resources and sound environmental policies. However, we are also challenged with an ongoing energy shortage and an underutilized economy. The Million Solar Systems initiative will save customers and the state $16 billion while at the same time providing for our long-term energy needs and improving both our economy and our environment.

2. Purpose of White Paper

- Assist the Governor's Office in the development of the Million Solar Systems Initiative

- Develop a framework for evaluating the net benefits that solar energy can provide to California: the *Million Solar Systems Model*

- Provide impartial, market-based data and a consistent set of assumptions as a basis for recommendations

The Governor of California is currently seeking to stimulate the growth of solar energy within California to improve the stability of the state's energy resources while reducing the environmental impact of those resources and improving the state's economy. The fundamental purpose of this report is to examine the overall benefits that solar can provide in the context of the range of subsidies that offset the initial cost of these systems.

From the perspective of the solar contractors that have contributed to this report, we believe that our state is best served if conservative and accurate figures are used to develop our state's solar policies. To ensure that the recommendations in this report are objective and credible, the assumptions and data used in this report are drawn from reliable, real world, market-oriented sources.

All of the sources for the data and assumptions used in this report are documented and are accepted as balanced and credible. These sources include the California Energy Commission, the California Public Utilities Commission, Stanford University, University of California, Berkeley, and others. Where specific surveys for equipment savings and costs were not available, conservative and market-based estimates were made.

Solar energy systems can make a substantial contribution to California's energy and economic situation while at the same time improving our environment and energy independence. This report looks at the real world benefits that both solar electric (also referred to as photovoltaic) and solar thermal (providing domestic hot water and pool heating) systems can provide to our state.

This report focuses on the tangible, quantifiable benefits of Distributed Generation solar technologies – solar electric and solar thermal generating systems that are located at the consumer's site. Both residential and commercial scale systems were examined covering both retrofit and new construction applications.

We have not examined the benefits of centralized, utility-scale photovoltaic systems, or centralized solar thermal generating systems. Although these systems may also be cost-effective, since they follow the conventional utility generation model they do not provide the same rapid deployment benefits, nor do they reduce the investments necessary in our energy transmission and distribution systems.

We have developed a framework for presenting the data and analysis contained within this report and for evaluating the total benefits that solar energy can provide to California, net of the costs of any incentives required to stimulate the market's adoption of this technology. The *Million Solar Systems Model* provides a sound methodology for deriving the incentives needed to drive end-customer behavior to achieve the state's desired goals as well as for calculating the value of the total benefits delivered to the state.

3. Objectives for the Million Solar Systems Initiative

- Achieve the greatest net benefit from distributed solar technology for California
  - Consider all of the benefits of solar
  - Evaluate the economic scenario in its entirety rather than piecemeal
- Drive solar adoption through effective, customer-focused, market-based incentives
  - Structure incentives to sufficiently motivate end-customer behavior to the desired level
  - Adjust incentives dynamically to remain in sync with changing market forces
- Achieve these benefits over 10 years

Governor Schwarzenegger is committed to the wider adoption of solar energy technologies in California. The Million Solar Systems Initiative is being developed as a plan that "helps the environment, offers homebuyers more choices, saves them and all ratepayers money, and contributes to a more stable energy market. The program will establish California as a world leader in solar technology, create new jobs, and encourage new manufacturing within the state." [1]

The Million Solar Systems Initiative offers a unique opportunity to achieve these benefits in a lasting manner for California by utilizing a market-based approach that accounts for the all of the costs and benefits of solar energy in economic terms.

Achieve the Greatest Net Benefit from Distributed Solar Technology for California

In order to receive the greatest return on investment of state resources, the Initiative should seek to maximize the benefits received from the solar systems installed as a result of the program. Since environmental improvements, customer savings, and energy infrastructure improvements, among others, are goals of the program, these benefits need to be quantified in economic terms and associated with unit quantities of solar installations.

[1] "Governor Announces Million Home Solar Plan," Update from the Governor's Office, August 20, 2004, http://www.governor.ca.gov/state/govsite/gov_htmldisplay.jsp?sCatTitle=%20&sFilePath=/govsite/spotlight/august20_update.html

Quantifying all of the benefits and costs of solar generation in this way enables us to evaluate this program from the overall perspective of California – rather than simply looking at its effects on contractors and consumers. or on utilities and ratepayers, for example. Alternative approaches which examine the economic effects of solar adoption in a piecemeal fashion, tend to ignore or underplay the substantial public goods delivered by solar generation.

In addition, analysis of individual effects of the program in different areas results in “apples to oranges” comparisons of costs and benefits. In order to obtain a truer picture of the real-world impact the program is likely to have, all of the various economic components should be studied together using a common set of assumptions.

Drive Solar Adoption through Effective, Customer-Focused, Market-Based Incentives

State programs to influence private markets should be market-based, rather than regulatory, in order to minimize total program costs and to encourage free market adoption of the desired behavior. In the case of solar generation, the most effective way to drive market adoption is to focus incentives on influencing end-customer behavior, since it is these end-users who ultimately decide whether or not to purchase solar systems.

In order to effectively influence customer behavior, incentives should be designed based on analysis of empirical market data. There is now a significant body of data within California that can reveal relationships between customer purchase decisions and solar system incentives and price levels. This information can be used to structure incentives that will drive the magnitude of economic behavior needed to achieve the Million Solar Systems program’s benefits.

Incentives in California must evolve, not only because of changes to the underlying economics of solar but also because of third party incentives. For example, if the $2,000 federal tax credit for solar is passed as part of a new federal energy bill, these additional $2,000 of customer savings should be considered when reducing California’s own incentives. Along the same lines, if the current 7.5% state solar tax credit is not renewed for 2006, the customer economics for solar will decline substantially on 1/1/2006.

We can also look to the experiences of Japan and Germany, whose earlier creation of substantial solar incentive programs has resulted in markets in those countries that are more mature and robust.

While some previous analyses have painted a more optimistic picture of solar economics, there is little to be gained by being overly optimistic about low system costs and high savings. If a program is implemented based on unrealistic assumptions, the market will correct for these errors and the likely result will be a much lower adoption rate or higher incentive costs than anticipated.

Achieve These Benefits Over 10 Years

The Governor's desire to achieve the results of this program within ten years is wise. Delay simply reduces the benefits available to Californians and dilutes the impact the state can have on cost-effectively improving its energy infrastructure, the environment, and the economy. As the timeframe for program implementation stretches out, the opportunity costs, in the form of infrastructure costs incurred, pollution not abated, and jobs not established, increase substantially.

Moreover, designing a long-term program provides certainty for the necessary manufacturing and installation infrastructure to meet these goals. If the experience of Japan in any indication, at the end of this ten year period there will be a sustainable solar industry in the state that will not require incentives and will continue to provide the benefits outlined in this paper in future years.

Summary: Guiding Principles for an Effective Solar Initiative

In summary, we believe there is a set of guiding principles which, if utilized, can ensure the development and implementation of an effective, cost- and time-efficient solar systems program that will deliver the benefits envisioned by the Governor's Office. We have incorporated these principles into the *Million Solar Systems Model* and the recommendations contained here. These principles are:

- Include and quantify all of the benefits of solar when evaluating total cost-benefit of the program
- Consider the economic scenario as a whole rather than looking individually at smaller parts, in order to best gauge the solar initiative's total, real-world impact
- Create market-based incentives that drive end-customer behavior
- Base analyses on actual market data to ensure effectiveness
- Retain the 10-year timeframe to provide assurances for long-term industry investment

4. Solar Market and Dynamics

- The Solar Distributed Generation Market is Complex
- Customer Economic Factors Drive the Market
- Several Critical Factors Influence the Market
- Examples from other Solar Programs
- The Million Solar Systems Initiative Can Achieve Its Objectives With Appropriately Targeted Incentives

The Solar Distributed Generation Market is Complex

Market segments

There are several solar generation technologies and customer segments that comprise the solar distributed generation market. These market segments are divided into two categories, Solar Electric (Photovoltaic) systems, which produce electricity directly from the sun, and distributed Solar Thermal systems, which utilize the sun's heat in place of electricity or natural gas to heat water.

The Solar Electric marketplace can be divided into four market segments: Residential Retrofit, Residential New Construction, Commercial, and Government/Public Buildings.

The Solar Thermal market is segmented into Domestic Hot Water (DHW) and Pool Heating used for residential applications. We have not considered commercial scale DHW and pool heating systems explicitly. Note that this report does not address solar thermal technologies used for electricity production as these are not used in distributed applications today.

Together these segments represent an installed base of approximately 184,000 operational solar systems in California today (see Figure X).[2] These are discrete installed systems and have not been converted into "solar system equivalents" as described in more detail in Section 6.

[2] Source: *Million Solar Homes Model*

Solar System Installed Base (2004)	
PV Res Ret	10,203
PV Res New	1,754
PV Commercial	313
PV Government	58
DHW Ret Electric	4,604
DHW Ret Gas	41,432
DHW New Electric	476
DHW New Gas	4,283
Pool	121,292
Total	184,414

Figure X

Each of these segments is described below in more detail below.

Solar Photovoltaic

Adoption of photovoltaic (PV) technology across market segments has increased significantly in California thanks to state rebates and tax credits -- and to rising electricity rates. Segments are differentiated by type of customer, as each faces a different economic equation when considering PV. Note that PV system size ratings in this report are based on peak DC watts. As described in Section 6, these peak DC watt ratings are about 20% higher than the AC system ratings used by the California Energy Commission.

Residential Retrofit

The residential retrofit market, where a PV system is added to an existing home (either as a roof- or ground-mounted system), is easily the largest PV segment in terms of number of systems. There are indications that average size of system installed by consumers has been increasing. Today's average residential retrofitted system is approximately 5.5 kW[3] and the average residential retrofitted cost is $40, 204 or $7.28 per watt[4]

Residential New Construction

New homes constructed with solar electric systems already installed represent a relatively new market segment in California. As builders have recognized both the incentives available for including solar in new home construction as well as increasing consumer interest in solar and other renewable technologies, the number of residential developments where solar electric systems are included or are an option is slowly increasing.

Data from the CEC database from 2003 through mid-2004 were analyzed to determine average new construction system costs and sizes [5]. Data on approximately 1,755 planned or

[3] "Solar Dealers 2004," Coast Hills Partners, p.30. CEC watts converted to DC Watts.
[4] *Million Solar Systems Model*
[5] *Million Solar Systems Model*

installed systems were extracted based on clusters of similar sized systems in locations installed by the same contractor (or dealer) and registered by the CEC at a similar date. Based on this analysis the average new construction system size is 2,102 watts and the average new construction cost is $14,932 or $7.10 per watt[6].

Note that the new construction installation price per watt is not very different than the residential installation price. There are several explanations for this result, including the possibility that installing PV systems in new homes is not quite as standardized as other building systems, new home builders are actually charging customers a premium for the PV option, installing smaller systems is not as cost effective as larger retrofit systems, or that new home builders are charging full retail price for this option and using the rebate as an extra source of profit margin.

Commercial

Commercial, or business, interest in PV has grown rapidly in the last few years with the higher levels of incentives available for commercial size systems through the CPUC's Self Generation Incentive Program plus the additional Federal incentives reserved for businesses (10% tax credit and accelerated depreciation).

A wide range of businesses can benefit the most from solar electric systems and thus are considered target customers for solar. Commercial customers seek cost savings now and in the future as well as, in some cases, the opportunity to conduct "green marketing" to their own customers. Long-term building occupants and relatively high power users are obvious candidates.[7] The average size for large commercial PV system installed in California today, based on the California Self-Generation Incentive Program ("SelfGen") database, is approximately 136 kW installed at an average cost of $7.00/watt.[8] In addition to the larger systems installed under the SelfGen program, the CEC's Emerging Renewables program has funded many smaller commercial systems. Coast Hills Partners found the average commercial system to be 66kw at an average cost of $6.94/watt[9].

Note that the CEC data and SelfGen data show that there are no significant economies of scale for commercial PV installations. There are several explanations for this result, including the fact that many large systems require additional support structures or roof reinforcement, and the design of the SelfGen incentive program with a 50% cap and a $4.50/watt incentive led many systems to be priced in such a way to maximize the incentive. For the purposes of this report the average commercial system size is assumed to be 100kw installed at $6.97/watt.

Government/Municipal

Government and municipal organizations can benefit from PV adoption similarly to commercial businesses. In addition to cost savings, some governmental entities have the added motivation of wanting to set a "green" example by utilizing renewable energy resources.[10] In the CEC and SelfGen databases, data for government systems is intermingled with that of commercial systems.

[6] *Million Solar Systems Model*
[7] "Solar Dealers 2004," Coast Hills Partners, pp. 36-38.
[8] Statewide Self-Generation Incentive Programs Statistics, http://www.sdenergy.org/uploads/SelfGen_Statewide_Data%20_June04.xls
[9] "Solar Dealers 2004," Coast Hills Partners
[10] "Solar Dealers 2004," p. 38

Note that the CEC data and SelfGen data show that there are no significant economies of scale for Government PV installations. There are several explanations for this result, including the likelihood that prevailing wage requirements add to system costs, many large systems require additional support structures, and the design of the SelfGen incentive program with a 50% cap and a $4.50/watt incentive led many systems to be priced in such a way to maximize the incentive. For the purposes of this report the average government system size is assumed to be 200kw installed at $6.97/watt.

Solar Thermal

The solar thermal technologies considered in this report are systems that heat water either for home use (Domestic Hot Water, or DHW), or for swimming pools. Both types of system have been marketed within California for some time, and both represent a type of renewable energy source in that the solar heat used offsets demand for electricity or natural gas.

DHW

Domestic Hot Water systems are designed to preheat water using a glazed rooftop solar collector connected to a home's hot water system. There are a variety of designs for these systems, including rooftop tank storage systems, tankless systems and active (pumped) systems. For the purposes of this report this analysis assumes that active DHW systems are representative of the lifecycle cost and savings of systems installed in California. The majority of homes in California use natural gas or electricity (and sometimes propane) to heat water. This report analyzes natural gas and electric systems separately. The average DHW system in California has approximately 64 square feet of collector area[11] and costs approximately $4,200 fully installed.[12] Duke[13] estimates the discount for new home construction PV installations to be 20% less than retrofit installations; we have used this discount percentage for installations of DHW systems on new homes.

Pool

Solar pool heating systems again displace electric- or gas-fired pool heaters. Pool solar systems use unglazed collectors connected to the pool's existing filter pump. Water is pumped to the roof whenever the filter pump is operating and the temperature of the pool will be increased by circulating water through the collectors. This report analyzes the energy savings for replacing natural gas fired pool heating system with a solar pool heating system (it would be extraordinarily costly to heat a pool with electricity in California). The average pool system in California has approximately 325 square feet of collector area[14] and costs $5,000 fully installed.[15]

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[11] Source: Les Nelson, Western Renewables
[12] Source: Jeff Brown, Solahart All Valley; Mike Daly, Sierra Pacific Solar
[13] "Clean Energy Buydowns: Economic Theory, Analytic Tools and the Photovoltaic Case," Richard D. Duke
[14] Source: Les Nelson, Western Renewables
[15] Source: Jeff Brown, Solahart All Valley

Customer Economic Behavior Drives Market

The true drivers of the solar market are end-customers making purchase decisions in each segment. Although there is a great deal of political support for solar amongst various segments of the population, at the end of the day these purchase decisions are economic decisions in which the customer roughly calculates his/her own net benefit from adopting a solar technology.

As shown in Figure X, the customer calculus includes all of the factors driving the cost of the solar system and comparing those to the potential savings the system can provide plus any "public good" factors (e.g., contributing to improving the environment). The current lack of a sufficiently adequate economic payback for many potential customers is a plausible explanation for the very high levels of support expressed for solar[16] even while adoption rates are still relatively low.

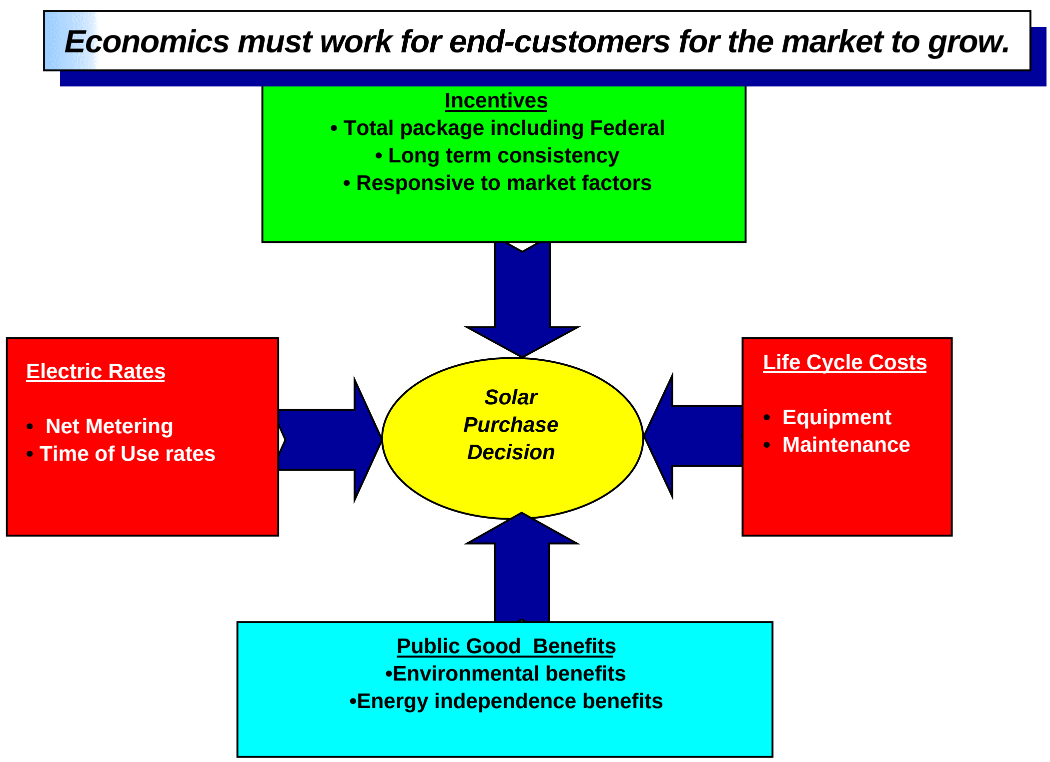


Figure X

For consumers, while the public good benefits of solar are often what may motivate a customer to investigate solar in the first place, it is important to note that the purely economic

[16] "Californians Support Solar – Survey," July 5, 2004, http://www.greenconsumerguide.com/index.php?news=2012

equation must work for a purchase decision to be made. A recent survey of photovoltaic dealers regarding their customers' characteristics indicated that those consumers who make decisions purely or even mostly on environmental grounds are a small percentage of total purchasers, and in fact, an increasing proportion of new customers were motivated primarily or exclusively by economic factors.[17]

Commercial customers are entirely motivated by the economic benefits achievable through solar adoption, which include near-term savings, insulation from future electric rate increases, and promoting their own businesses through solar use.

Government customers are often motivated thusly as well, with some exceptions where the government entity wants to set an example by adopting solar.[18]

Critical Factors Influencing the Market

A variety of factors influence the market for solar energy systems by affecting the economic equations considered by customers. Thus it is important to take into account all of these effects when considering which incentive levels will achieve the state's goals.

Annual Savings: Electric Rates and Net Metering

Major considerations influencing solar system purchase decisions hinge on current and expected electric rates. As electric rates rise, so do the anticipated savings the customer can expect to derive from installing a solar PV or thermal system.

At the same time, Net Metering and Time of Use rates are crucial parts of the customer's cost-benefit evaluation because the ability to sell excess power back into the grid effectively reduces the cost of the solar installation. If the ability to sell back excess power and the rates at which this can be done are reduced, the net cost to the customer rises and greater incentives will be needed to achieve the same levels of overall benefits for the state.

Life Cycle System Costs

Life cycle system costs must include the net up-front equipment and installation costs, plus any anticipated maintenance over the lifetime of the system. Up-front solar system costs are slowly declining, as greater production of solar system components worldwide benefits from experience curve effects as well as the continued development of a stead and experienced installation workforce (For example, from 1976-2000, for each cumulative doubling of PV module production, unit prices dropped 20%).[19] We may continue to see declining prices as global capacity increases and balance of systems costs are reduced (inverters and support structures), once the current short-term supply shortfall has eased.

Expected maintenance costs are factored in to the purchase decision and serve to increase the effective costs of the system for the customer. Typical maintenance expenses include equipment repair or replacement as parts reach the end of their useful lives. The more reliable

[17] "Solar Dealers 2004," Coast Hills Partners, p.29.
[18] "Solar Dealers 2004," Coast Hills Partners, p.38.
[19] Bernie Fischlowitz-Roberts, "Sales of Solar Cells Take Off," Earth Policy Institute Eco-Economy Update, June 11, 2002, http://earth-policy.org/Updates/Update12.htm

the system components are the lower the life cycle cost -- and the higher the customer's return.

Renewable Energy Credits and Renewable Portfolio Standards

Renewable Energy Credits (RECs)

RECs are tradable commodities that represent the avoided pollution benefits from renewable power generation. One REC is equal to one megawatt hour (MWh) of renewable energy that is physically metered and verified from the generator, or the renewable energy project. Although California does not yet have a tradable REC market, other states and countries do. These RECs can amount to serious money depending on the demand and trading volume. For example, RECs in New Jersey are being offered for trade in the range of $1,000 to $2,000 (roughly equal to the *retail* cost of electricity). Once trading markets become more established it is contemplated that RECs will trade more in the range of $500.

The issue for the state relates to the ownership of these RECs that result from the installation of a renewable energy system. Since RECs are essentially a property right, the owners and purchasers of a renewable energy system should own and benefit from these rights. Assigning the right to the utility would effectively violate the property ownership rights of the customer. Moreover, as a robust trading market for RECs develops, it is anticipated that the trading value of these rights could be made to equal the effective pollution benefits of the rights and represent a significant customer benefit – thereby reducing the direct state incentives required in future years.

Renewable Portfolio Standards (RPS)

The goal of the RPS is to reduce the impacts of pollution throughout the state. Since pollutants do not respect geographical boundaries, having these requirements apply differently to IOU and MOU utilities would have the effect of shifting costs and pollutants. Moreover, it is our position that the RPS should apply only to power generation sources that are truly renewable so that there would not be any negative environmental impacts.

Incentive Structure and Administration

Not only are the raw levels of incentives important for stimulating demand in the solar marketplace, but the structure and administration of those incentives can also have a substantial impact on their effectiveness. Complex application processes and provisions in excess of requiring the customer to purchase and use an effective solar system create hidden disincentives that reduce the impact of the incentives by effectively increasing the cost to the customer. Administrative delays and errors can substantially add to installer and manufacturer costs – which are ultimately passed on to consumers.

In general, current CEC and SelfGen programs are effective and bureaucratically straightforward – especially when compared to PV programs in other states. Continued efforts to streamline these CEC and SelfGen programs (consistent with necessary controls) will serve to reduce overall costs in the industry.

Incentives must also be attuned to global market forces in order to remain effective. For example, over the past year, a global solar module shortage has caused equipment prices to actually increase (not only have module prices increased, but credit terms have been tightened and shipments have been reduced). Existing PV rebates in California have stepped down three times during this period, although these reductions anticipated a continued decline in equipment and installation costs – an assumption that has not been true during the module shortage that began in 2004.

Potential customers have seen effective price increases for PV systems as incentives have dropped while module prices have remained steady or increased. Not surprisingly, growth rates have slowed somewhat in most PV market segments. To avoid these industry growth disruptions, incentive programs must utilize current and historical market data from a variety of sources to better predict and understand customer behavior patterns.

Finally, consistency and predictability is essential for both customers and suppliers of solar PV or thermal systems. Funding interruptions, unanticipated processing delays, and unpredictable program changes all serve to undermine market confidence, reducing customers' willingness to purchase and industry's willingness to invest in expansion, workforce training, specialized equipment and facilities -- resulting in lowered effectiveness of the incentive program.

Examples from other Solar Incentive Programs

Japan

The experience of Japan provides a useful history that we can examine to evaluate the effects of incentives designed to aggressively hasten the development of a private market. The Japanese government's initial goals were to first spur the development of PV technology, and then to stimulate mass production that could sustain a domestic private market as well as dominate the international market.[20] The 70,000 Roofs Program, begun in 1994, initially covered 50% of new PV system costs. At the time, installed system costs per Watt were around $11; 539 systems were installed that year. Over the next nine years, the number of systems grew to over 168,000, representing 200 MW of capacity, and prices per Watt fell to around $6. Also during this time, incentives dropped as well, from 50% in 1994 to 10% in 2003.[21]

Japan also promoted the solar industry by providing research and development funds (approximately $186 million in 2003), demonstration programs and other promotions, and net metering, improving the economic equation for the customer. Japan's PV market now sustains itself without incentives.

[20] Oliver Ristau, "The Photovoltaic Market in Japan," Solar Magazine, September 15, 2001, http://www.solarserver.de/solarmagazin/artikelseptember2001-e.html
[21] Paul Maycock, "PV Market Update," Renewable Energy World, July 2004, http:///www.jxj.com/magsandj/rew/pv_market_update.html

Germany

Germany has taken a different, but also aggressive approach to promote solar adoption. Germany launched its 100,000 Solar Roofs Program in 1999 featuring low interest loans for system purchases. In 2001 they boosted their net metering rate (also called a feed-in tariff) significantly. As a result of these programs, German installed capacity of distributed PV grew from less than 50 MW in 1999 to 400 MW expected by the end of 2004[22]. The German PV industry generates over 10,000 jobs in production, distribution and installation.

This "Feed-in Law" in Germany permits customers to receive preferential tariffs for solar generated electricity depending on the nature and size of the installation. Under the new tariff structure introduced in 2004, the base level of compensation for ground-mounted systems can be up to 45.8 euro cents/kwh. PV installations on buildings receive higher rates of up to 57.4 euro cents/kwh[23].

Hawaii

Domestically, Hawaii has experienced success with its incentive programs for renewables, particularly for solar thermal (DHW). Between 1996 and 2001 the installed base of solar hot water heaters grew to 85,000 with approximately 3,500 systems being added per year by 2001.

Hawaiian incentives for solar DHW include:

- 35% tax credit (through 2008)[24]
- $750 to $1,000 utility rebates (higher for commercial)[25]
- Net Metering[26]

The State of Hawaii has recognized significant direct benefits from solar DHW alone, according to the Hawaiian Energy Resource Coordinator's 2003 Report[27]:

"Analyses have shown that every dollar spent by the state for the residential renewable tax credit generated $1.82 in tax revenues. The total tax revenue effect for installations between 1996 and 2001 – primarily solar water heaters – is nearly $37 million. There are now more than 85,000 solar water heaters statewide, the highest number per capita in the U.S. These systems have saved Hawaii consumers $240 million, reduced oil consumption by more than 4 million barrels, and provided 1,800 jobs for Hawaii residents."[28]

Note that these calculations do not include any environmental or avoided energy cost benefits.

[22] Maycock, "PV Market Update"
[23] Solarbuzz, http://www.solarbuzz.com/FastFactsGermany.htm
[24] "Energy Tax Credits," http://www.hawaii.gov/dert/ert/taxcredit.html
[25] http://www.hawaii.gov/dbedt/ert/taxcredit.html
[26] http://www.hawaii.gov/dbedt/ert/netmeter.html
[27] Energy Resources Coordinator's 2003 Annual Report, http://www.hawaii.gov
[28] Energy Resources Coordinator's 2003 Annual Report

Conclusions from examples

Each of these solar growth efforts has utilized a similar set of incentives with varying degrees of emphasis on each component.

Program	Rebates	Tax Credits	Low Interest Loans	Net Metering
California (PV)	X	X		X
New Jersey (PV)	X			X
Japan (PV)	X			X
Germany (PV)			X	X
Hawaii (DHW)	X	X		

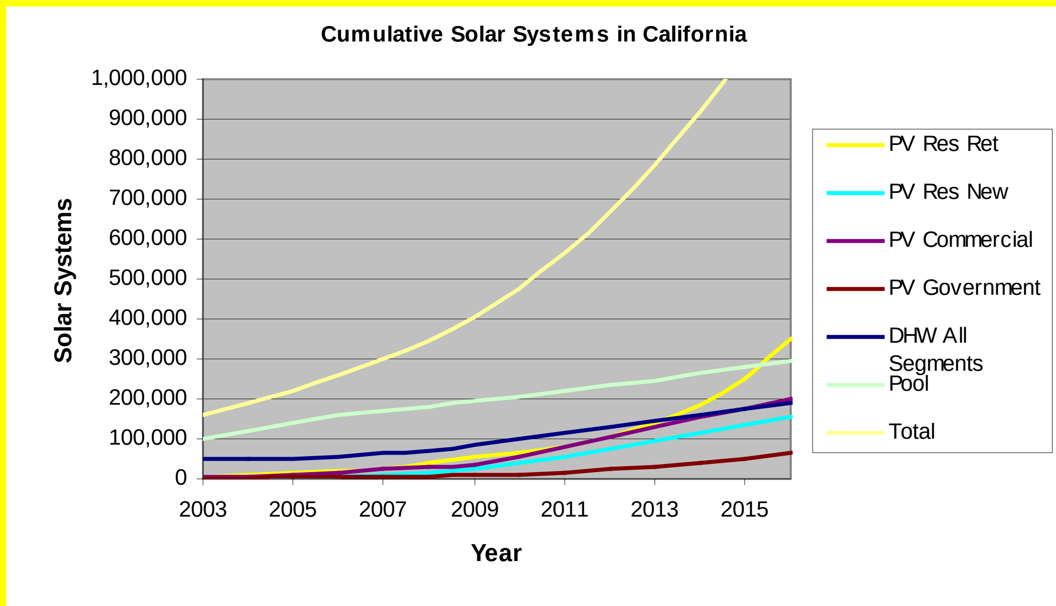
It appears that, regardless of the components of the incentive package, the most important element of success is reducing the customer's net cost sufficiently so that the customer perceives a positive economic payback.

Another important factor, which has not been evaluated here, is the role of public awareness and program promotion. California's successful "Flex Your Power" campaign has achieved high public awareness and has persuaded thousands of customers to take advantage of utility rebate programs. Increasing customer awareness of California's Million Solar Systems incentive program would be a very good use of a subset of available incentive funding.

The *Million Solar Systems Model* includes analyses of these data sets in order to infer price elasticity of demand. Particularly as more countries and states gain greater experience with a variety of solar programs, much can be gained by incorporating new customer elasticity and product lifecycle information in an effort to more accurately predict customer behavior.

The Million Solar Systems Initiative Can Achieve Its Objectives With Appropriately Targeted Incentives

With appropriately sized incentives the Million Solar Systems Initiative can achieve its targets of over one million cumulative solar installations in California by 2016. The critical factor is to size incentives correctly in each market segment to drive customer purchase decisions at the necessary growth rates. The graph below shows the relative starting points and contributions that can be expected for each market segment. Note that the count is made in terms of solar system equivalents, valuing commercial and government systems at a higher level based on their greater installed capacity.



Summary

In summary, the solar market in California consists of several customer segments that are serviced by two primary solar technologies, solar electric (photovoltaic or PV) and solar thermal (for domestic hot water and pool heating).

Although these segments may be diverse with respect to customer types of applications, they possess in common the fact that end-customer's calculations of economic costs and benefits are the fundamental market driving force.

A number of critical elements -- such as electric rates and life cycle costs -- affect the market by altering the customer's cost-benefit assessments, and therefore their purchase behavior. Thus, it is crucial to evaluate any changes in these elements in the context of their impact on the overall demand for solar.

Examples of successful solar programs abound – including our own experiences thus far in California -- provide us with important data that we can use to model real-world customer behavior. This modeling can then be used to structure incentives designed to achieve the Million Solar Systems Initiative's objectives.

5. Million Solar Systems: Benefits to California

- Energy and Capacity: The Avoided Costs of Generation, Transmission, and Distribution
- Environmental Benefits: Reduced Criteria Air Emissions and CO2 Insurance
- Economic Savings
- Customer Savings
- Negligible "Cost-Shifting"
- Public Policy Benefits

Solar electricity can provide California with a major new source of electric generation. Importantly, solar generation will provide most of its electricity on summer afternoons, precisely the time period when the state's demand for electricity peaks. Because it is a peaking resource, solar generation offers the state greater energy benefits, per kilowatt-hour, than other types of renewable generation. Solar thermal production of domestic hot water will reduce the consumption of both natural gas and electricity in conventional water heaters

As a zero-emission source of electrical and thermal energy, solar will result in significant reductions in both criteria air pollutants (oxides of nitrogen [NOx] and particulates) and in carbon dioxide (CO2). The reductions in CO2 emissions can be viewed as important insurance against the potential for serious impacts from global warming.

Finally, California also has the opportunity to play a decisive role in the growth of a major new high technology industry, one that is uniquely tailored to California's strengths and that will provide the state with significant benefits in terms of job creation and economic activity.

This section calculates the benefits to California from continued growth in the state's solar resources. In making these calculations, we have not attempted to "re-invent the wheel;" instead, we have used currently available models with up-to-date input assumptions.

Energy and Capacity: The Avoided Costs of Generation, Transmission, and Distribution

The benefits to electric customers of a new source of generation typically are calculated by determining the "avoided costs" of the new generation — that is, by calculating the costs that the local utility does not need to spend as a result of the new source of power. Solar generation that serves a consumer on his premises will avoid the need for the local utility to provide the consumer with electric energy (kilowatt-hours). The consumer's ability to produce power also may allow the utility to avoid the need to build generating capacity (kilowatts) to meet the system's peak demand. Solar generation may be a particularly valuable source of capacity because it tends to produce significant power during summer afternoons when California's demand for power peaks. Furthermore, because the customer is producing power at his home or business, solar generation can avoid the need for the utility to construct addition transmission and distribution (T&D) lines to bring power from the utility's own generation to the consumer, and less energy is lost moving power through those lines.

Calculating avoided costs has been a standard practice in the utility industry since the late 1970s. In 1978, in response to high oil prices and the "energy crisis" of the 1970s, Congress passed and President Carter signed the Public Utilities Regulatory Policies Act (PURPA). This legislation required the nation's utilities to buy the power output of independently developed power plants using renewable or cogeneration technologies, plants known as "qualifying facilities" or QFs. PURPA required utilities to pay prices for QF power equal to their avoided costs, as determined by the public utilities commission in each state. Today, QFs supply about 25% of the power needs of California's investor-owned utilities, and the CPUC has 25 years of experience in setting avoided cost prices for QFs in California. Avoided costs also are used to assess the cost-effectiveness of energy efficiency programs. The costs that a utility avoids if a customer generates a kilowatt-hour at his home between 2 p.m. and 3 p.m. in the afternoon are the same as the costs that the utility avoids if the customer reduces his household demand by a kilowatt-hour during that same hour.

The CPUC has an ongoing proceeding to review its current practices for calculating avoided costs. As part of this process, the CPUC's Energy Division commissioned a consultant report (the "E3 Report"), released early in 2004, setting forth a comprehensive approach to the calculation of long-run (20 year) avoided costs for the investor-owned utilities (IOUs) in California.[29] The E3 Report's methodology calculates avoided costs for generation (capacity and energy), transmission, and distribution, as well as certain environmental costs. The E3 Report also calculates the natural gas costs avoided by measures that reduce natural gas consumption at the point of use. The E3 Report includes a detailed spreadsheet model for performing the required calculations.

E3 released a final version of its report and model on November 2, 2004.[30] In a chapter responding to the comments that it has received on its Report and model, E3 emphasizes that its work is most appropriate for evaluating resources with the following characteristics:

- Reduce load or produce energy for hundreds of hours per year in a predictable pattern. Reductions over hundreds of hours reduce the importance of knowing the exact shape of the electric generation market hourly shape during the peak hours. The predictable pattern reduces issues related to uncertainty over the timing and reliability of the load reductions.

- Are relatively small (such that they can be installed behind the customer meter). The smaller the resource relative to the local T&D system, the less the utility needs to plan for the contingency case of the resource failing to provide reductions. This is especially true for the

29 "A Forecast of Cost Effectiveness Avoided Costs and Externality Adders," prepared by Energy and Environmental Economics for the CPUC Energy Division. The initial draft of this report was released January 8, 2004 to parties in CPUC R. 01-08-028.

30 The updated E3 Report is now titled "Methodology and Forecast of Long term Avoided Costs for the Evaluation of California Energy Efficiency Programs."

local distribution system. If the resource is small so that the utility can plan its T&D capacity additions based on the expected net load of customers (not the load of customers under the contingency case), then those resources can be credited with generation and T&D capacity savings.

- Are expected to be installed in large numbers. The more resources that are installed, the more diversity one has, and the more one can rely upon the expected level of reductions (assuming that the resources do not have a common failure mode). Also, the more resources that are installed, the more likely that the resources will provide sufficient load reductions to actually defer local T&D projects.[31]

We believe that solar technologies meet all of these criteria, and thus the E3 methodology is a suitable tool for calculating the avoided costs associated with California's solar resources.

We have used the E3 Report's model to calculate the avoided cost benefits to California from future development of the solar market in California. The key input assumptions for the E3 Report's avoided cost model include:

- Natural gas price forecast. We have used recent[32] natural gas futures prices from the New York Mercantile Exchange (NYMEX) to develop a long-run forecast of natural gas prices in California. Our forecast is generally consistent with the approach to long-term gas forecasting used in the E3 Report and the RPS program. The CPUC recently approved this approach in D. 04-06-015. Figure X shows our long-term gas price forecast.

- Marginal costs for transmission and distribution. We have used the most recent values for PG&E's marginal costs for transmission and distribution, as filed by PG&E in its ongoing general rate case before the CPUC.[33] The E3 model also includes data for the utility's line losses, the percentage of electric energy that is lost as heat in the T&D system. Solar generation that is sited at the point of use avoids line losses.

- Costs for the avoided generation resource. Approximately 40% of the generation serving California is natural gas-fired. In most hours, a gas-fired power plant is "on the margin," providing the last megawatt-hour used to serve load. The cost of this marginal gas-fired generation sets the avoided cost price for energy. In recent years, most of the generating capacity added in California has been combined-cycle gas turbine (CCGT) plants. The E3 Report assumes that, in the long run, new renewable generation will avoid the need to build additional CCGTs. Thus, the E3 Report bases its avoided generation costs for both energy and capacity on the full, "all-in" costs of a CCGT.

In the spring of 2004, the CPUC conducted workshops that developed a detailed model for the all-in costs of a CCGT, for use in the RPS program. In D. 04-06-015, the CPUC approved this model. We have verified that the E3 model's calculation of CCGT costs is very similar to the CPUC's approved model.[34] As part of upcoming solicitations for new renewable generation under the RPS program, the CPUC will be selecting input assumptions and approving all-in CCGT costs. For this white paper, we have used what we believe to be "middle of the road" input assumptions for the operating, capital, O&M, and financing parameters of a new CCGT, based on parties' presentations in the RPS workshops and comments.

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31 See Updated E3 Report, at 247.

32 We used gas futures market prices as of October 15, 2004. Natural gas market prices have been volatile recently; these prices fall in the middle of the range of recent gas prices.

33 See PG&E's June 2004 testimony in Phase II of its ongoing general rate case, A. 04-06-024, Table 1A-5.

34 E3 also agrees with this point. See Updated E3 Report, at 257 – 258.

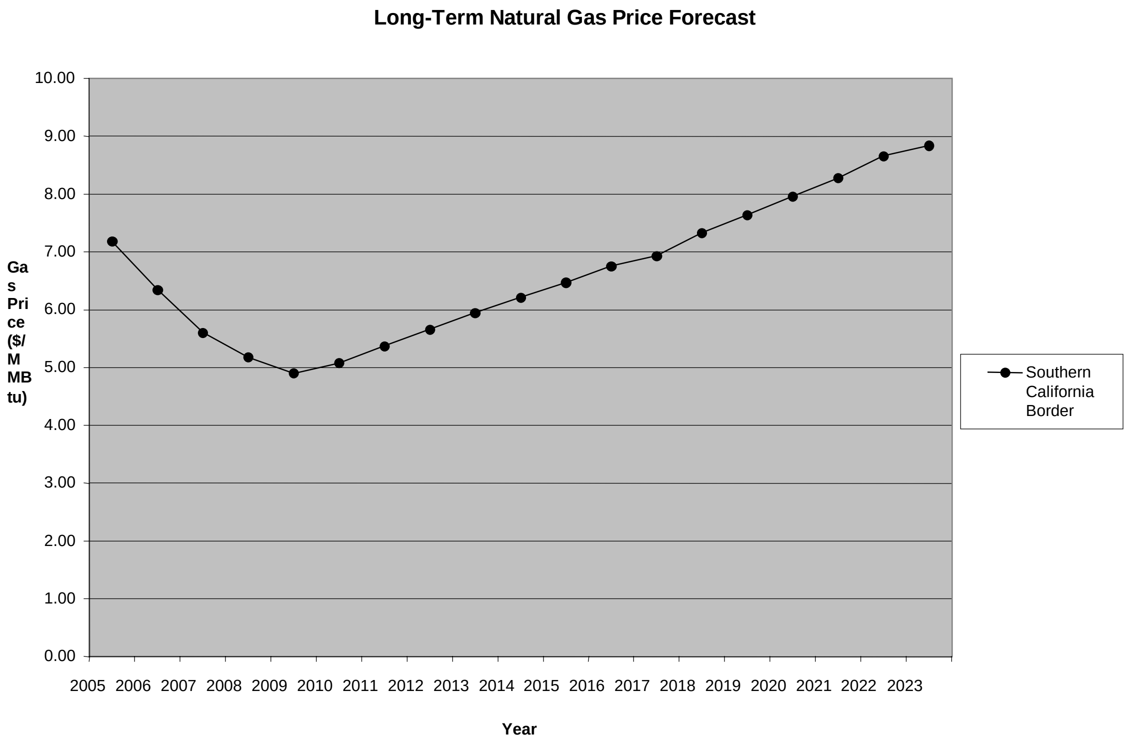

Figure X

- Resource balance year. The E3 Report assumes that California has adequate generating resources until 2008; as a result, the E3 Report's avoided costs do not reflect the full cost of a new CCGT until 2008. Through 2007, the E3 model uses forward market prices instead of CCGT costs. However, the California Energy Commission (CEC) has found that the state could experience electric supply shortfalls – particularly in southern California -- as soon as the summer of 2005 under adverse conditions,[35] and the IOUs have continued actively to seek new resources. Further, on October 28, 2004, the Commission approved a decision (D. 04-10-035) setting forth the details of its resource adequacy requirements, which will require the state's utilities and other load-serving entities (LSEs) to acquire enough capacity to maintain 15% to 17% reserve margins. At the governor's request, the CPUC majority agreed to accelerate the deadline for meeting the resource adequacy goals, from the summer of 2008 to the summer of 2006. To meet this aggressive goal, the IOUs will need to acquire additional resources in 2005 and 2006. As a result, we have used CCGT costs throughout the 20-year forecast period.

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[35] See the CEC's "Integrated Energy Policy Report 2004 Update" (November 2004), Tables A5 and A6, available at http://www.energy.ca.gov/2004_policy_update/documents/index.html.

We have made one conceptual change to the E3 model. The E3 Report assumes an integrated market for both energy and capacity in California, with all-in CCGT costs as the combined measure of both energy and capacity. The ill-fated California Power Exchange was such an integrated energy and capacity market. Today, however, California is taking a new course, and the state is developing a distinct capacity market through the CPUC's resource adequacy proceeding. In particular, we expect that the state's new resource adequacy requirements will lead to an active capacity market, as the state's LSEs seek to acquire the needed capacity. Because California is expected to require new capacity to be built in the 2006 to 2008 time frame, the price for capacity is expected to rise quickly to the annual ownership costs of a simple-cycle combustion turbine (CT), which is generally used as the value for the least-cost new source of generating capacity alone. The CEC recently estimated the levelized annual ownership costs of a CT to be $80 per kW-year in 2004;[36] both Edison and PG&E have used similar CT values as the marginal cost of generating capacity in their current general rate cases.

To reflect the development of a capacity market in California, we have separated the all-in costs of a CCGT into distinct capacity and energy components. We assume that the capacity value equals the full cost of a CT; we assign the remainder of the CCGT costs to the energy component. The E3 model uses an hourly price profile derived from 1998 - 2000 hourly PX prices to convert forecasted annual energy prices into a forecast of 8760 hourly prices. We agree with this approach to forecasting hourly energy prices. However, in a departure from the E3 model, we do not also use this hourly profile to determine hourly capacity prices. Instead, we assign the capacity values to monthly and hourly periods on the same basis as the E3 Report's allocation of T&D costs. This allocation assigns capacity value predominantly to summer peak periods. We believe that this approach more appropriately reflects the fact that the CPUC's resource adequacy requirements focus on the availability of capacity to meet monthly peak demands in the summer months.[37]

The E3 model produces 8760 hourly avoided costs per year for a 20-year forecast period. Using the assumptions described above, we have run the E3 model to produce a set of hourly avoided costs. We then weight these hourly avoided costs by the monthly average hourly profile of a typical solar generator in California, to produce a 20-year stream of "solar-weighted" avoided costs. Figure X shows the annual average and solar-weighted avoided costs that we have calculated using the E3 model. Please note that these avoided costs include the environmental benefits discussed in the next section, but not the economic benefits and direct customer savings.

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[36] See "Comparative Cost of California Central Station Electricity Generation Technologies" (CEC Staff Final Report, August 2003), Appendix D. PG&E has used this value in its June 2004 testimony filed in A. 04-06-024, Table 2-9.

[9] See "Comparative Cost of California Central Station Electricity Generation Technologies" (CEC Staff Final Report, August 2003), Appendix D. PG&E has used this value in its June 2004 testimony filed in A. 04-06-024, Table 2-9.

[37] See, for example, D. 04-10-035, at 10 and Finding of Fact No. 1.

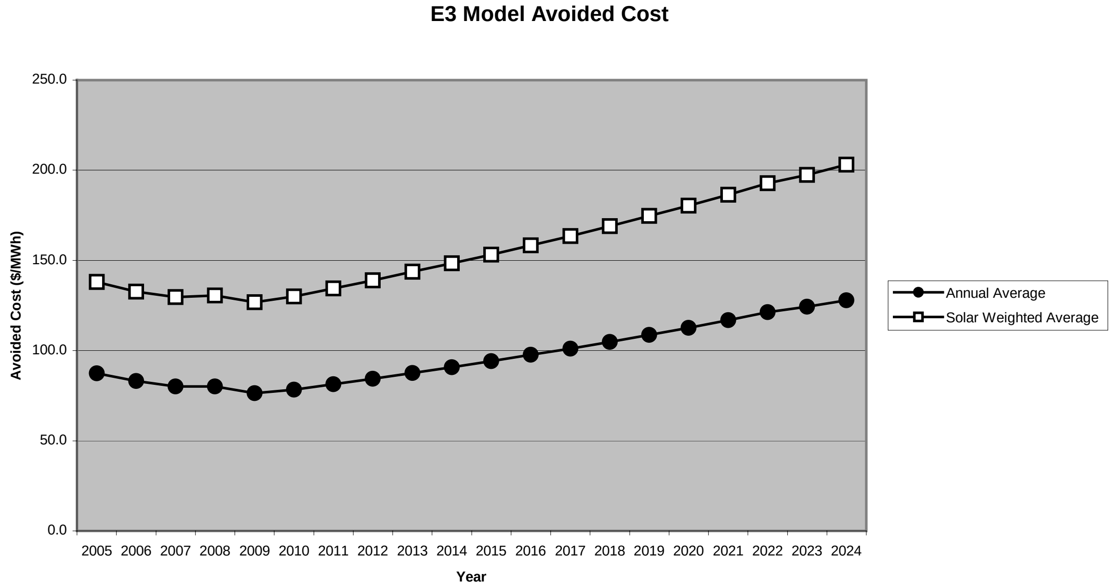

Figure X

Environmental Benefits: Reduced Air Emissions and CO_2 Insurance

The E3 model incorporates explicitly the value of some of the important environmental benefits of widely distributed solar generation:

First, by displacing natural gas-fired generation, zero-emission solar generation will reduce emissions of the criteria air pollutants that are regulated in California — NOx and particulates. The E3 model calculates the costs avoided by reducing these emissions, using emission rates from gas-fired generation and forecasts of the prices for both NOx and particulate emission offsets.

Second, solar also will reduce emissions of CO_2, the principal gas associated with the expected greenhouse warming of the global environment. In the U.S., CO_2 emissions are not regulated consistently at either the federal or state levels. Nonetheless, the CPUC has recognized that, in crafting its long-term avoided cost methodology, it needs to address the "potential financial risks associated with carbon dioxide emissions... as part of the overall question of valuing the environmental benefits and risks associated with current or future investments in generation plants..."[38]

We agree with the E3 Report's perspective that, over the next 20 years, it is highly likely that CO_2 will be regulated. During this time period, the costs of mitigating CO_2 emissions will become part of the marginal cost of burning natural gas and other fossil fuels. The E3 Report sets forth the following reasons to expect that CO_2 will be regulated in the future:[39]

- The Intergovernmental Panel on Climate Change (IPCC), a high-profile international science collaboration examining the state of scientific knowledge of climate change and its impacts, found in its latest report on climate change that "it is not a question of whether the Earth's climate will change, but rather when, where and by how much," and that "most of the warming observed over the past 50 years is likely to have been due to the increase in GHG concentrations."[40]

- The U.S. National Research Council's (NRC) Committee on the Science of Climate Change found that "the IPCC conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in GHG concentrations accurately reflects the current thinking of the scientific community on this issue. Despite . . . uncertainties, there is general agreement that the observed warming is real and particularly strong within the past 20 years."[41]

- The Kyoto Protocol to the UN Framework Convention on Climate Change was signed by 84 countries, including the United States, and has been ratified by more than 120 countries.[42] Even if the quantitative goal of the Protocol, to reduce greenhouse gas (GHG) emission from industrialized countries by 7% between 1990 and 2008-2012, is not achieved, the treaty is nevertheless a clear statement of international commitment to mitigate climate change.

- Several U.S. states have now regulated or are considering regulation of CO_2 and other GHGs in some form. A number of states in the U.S. Northeast have proposed to create a regional GHG cap-and-trade market system, and eleven states recently sued the U.S. Environmental Protection Agency over its refusal to regulate CO_2 under the Clean Air Act. California has enacted legislation to limit CO_2 emissions from cars. Oregon now requires new power plants to meet a CO_2 emission standard as a condition of receiving a siting certificate. This standard requires new natural gas-fired combined-cycle power plants to offset at least a portion of their CO_2 emissions. Offsets can be obtained by direct investment, by purchases on the open market, or by funding the Oregon Climate Trust, which serves as the standard's monetary compliance path.[43]

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[38] California Public Utilities Commission, D. 04-01-050,(January 2004) , Finding of Fact #61, pp. 190.
[39] See the Updated E3 Report, at 82 – 84.

[40] Intergovernmental Panel on Climate Change Working Group 1, 2001. Third Assessment Report Summary for Policymakers. http://www.ipcc.ch/.

[41] National Research Council, Committee on the Science of Climate Change, Division on Earth and Life Studies. Climate Change Science: An Analysis of Some Key Questions, National Academy Press, 2001. http://www.nap.edu
[42] The Kyoto treaty is now in force, as Russian recently completed its process to ratify the accord.

[43] *See* www.climatetrust.org

- There is now active international GHG trading among European Union countries. The United Kingdom, Denmark and the Netherlands have begun various forms of GHG trading. The World Bank's Prototype Carbon Fund (PCF) has been assembling carbon-offset projects for five years.

- Although the Bush Administration has opposed Kyoto ratification and GHG limits, there is legislative support in both major parties for climate change mitigation, as indicated by the 2003 Senate debate on the McCain-Lieberman bill, which received 43 Senate votes.[44]

We concur with the E3 Report that "regulation of CO_2 and other GHGs is a matter of when, not if."[45] We also expect that GHG regulation will be market based, such that there will be a transparent price for carbon emission credits. This price will increase the cost of burning fossil fuels such as natural gas to produce electricity.

Recent studies of various GHG mitigation strategies have shown the value of taking steps now to mitigate GHG emissions, without waiting until the world has more definitive information on the climate impacts of GHGs.[46] Immediate action functions as insurance against the potential that very expensive measures might be needed if the world waits to take action until the actual impacts of GHG emissions are more precisely understood. These studies show that action today, even at relatively modest costs of $10 per ton of CO_2 or less (or about 5 cents per gallon of gasoline), will minimize the future cost to the global economy of mitigating GHG impacts. The value of acting today derives from the uncertainty in the future impacts of increased GHG levels. Thus, what we do not know today means we should begin to act now — in the long run, the most expensive course is to do nothing.

These considerations convince us that it is appropriate to include a value for reduced carbon dioxide emissions in the costs avoided by solar generation. The E3 Report uses a modest value of $8 per ton of CO_2 in 2004, rising at 5% per year thereafter. This is significantly less than the current reported price of about $11.30 per ton for CO_2 credits in Europe.[47] Using this value, the avoided costs of CO_2 emissions constitute about 80% of the avoided environmental costs associated with solar power. This value of $8 per ton may be at the low end of a range of CO_2 values that the CPUC will use in the future. On November 16, 2004, CPUC ALJ Carol Brown recommended that the CPUC should direct the California IOUs to use a range of CO_2 values from $8 to $25 per ton in future evaluation of new generation resources.[48]

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[44] Climate Stewardship Act, United States Senate Bill, S.139, Sponsored by John McCain and Joe Lieberman, 2003.

[45] E3 Report, at 89.

[46] G. Yohe, N. Andronova, and M. Schlesinger, "To Hedge or Not Against an Uncertain Climate Future," *Science* (15 October 2004, Vol. 306), at 416; also, W.D. Nordhaus, *Econ. J.*, Vol. 101, at 920 (1991).

[47] "As Kyoto Protocol Comes Alive, So Do Pollution-Permit Markets," *Wall Street Journal* (November 8, 2004), at A2.

[48] See Proposed Decision of ALJ Brown in R. 04-04-003, mailed November 16, 2004, at 133-135.

Economic Benefits

California's investments in solar generation since 2001 have helped stimulate the development of a significant new high technology industry. Continued state support for the solar industry is crucial if the industry is to grow to the point that it is self-supporting. Importantly, investments by consumers and the state in solar generation will produce greater benefits for the California economy than will investments in the gas-fired CCGT and CT plants that they replace.

Several studies have attempted to quantify the economic benefits of the accelerated development of solar resources. The California Solar Energy Industries Association has used an input-output model (E3AS) developed by The Goodman Group (TGG). The E3AS software estimates the regional economic impacts of a new technology by tracing the industries involved through successive rounds of supply linkages. At each step, the program traces the portion of the inputs required from each industry that are supplied within the regional economy being modeled. The study concluded that each $1 invested in new solar generation would result in an additional $0.50 of economic activity in California, compared to producing the same power through conventional means. Included within this increased economic activity are more jobs for Californians: each megawatt of solar generation would produce an additional 40 person-years of employment.[49]

Professor Dan Kammen of U.C. Berkeley has also studied the incremental economic benefit associated with renewable energy. In an April 2004 review of the available studies on the jobs created by photovoltaic generation, Dr. Kammen cites estimates of 1.6 to 2.2 additional jobs created per MW of PV installed, over the life of a facility, compared to the jobs created by conventional electric generation.[50] Assuming a 20 to 25-year facility life, this results in very similar numbers to Cal SEIA's result of an additional 40 person-years of employment per megawatt installed.

Why will the solar industry produce more jobs and more economic benefits than comparable spending on conventional electricity supplies? The majority of the costs of natural gas-fired power production are fuel costs. California obtains only 15% to 17% of its gas supplies from in-state sources, so most of the spending for fuel does not benefit the California economy. In contrast, installing solar generation and thermal systems requires skilled local labor, and many solar components are manufactured in the state. If the state provides long-term support for the solar industry, suppliers will be encouraged to locate plants in the state, close to a major long-term market.

Customer Savings

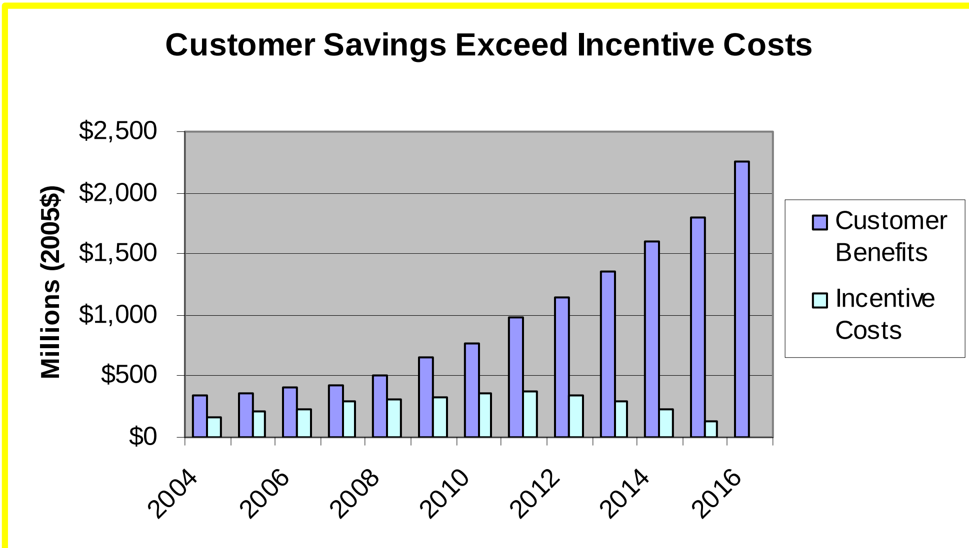
Implementation of the Million Solar Systems program in California will save a considerable amount of money for customers by directly lowering their out-of-pocket energy bills. As with

[49] "The Costs and Benefits of the Extension of California's PV Incentive Program," prepared by Powerlight Corporation for CalSEIA (June 2004), at 1, 6-8, and supporting spreadsheets.

[50] Daniel M. Kammen, Kamal Kapadia, and Matthias Fripp (2004), "Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?" (RAEL Report, University of California Berkeley, Energy & Resources Group, April 13, 2004).

the other quantified savings components in this Benefits section, these customer savings are based on the present value of the 20-year stream of energy savings that would accrue from the installation of solar capacity in each calendar year.

The following graph shows that these customer energy bill savings exceed the incentive costs in every year of the program.



From the overall standpoint of California's economy, these customer benefits are an additive savings. The dollars that these customers will now have to spend can be reinvested in California and continue to benefit our economy instead of being spent, to a large degree, on external fuel sources.

Negligible "Cost-Shifting"

Concern has been expressed that extensive development of California's distributed solar resources will have adverse impacts on the electric utility ratepayers that are unable to participate in the program, as a result of a "cost shift" from ratepayers that install solar to those that cannot.[51] This concern has focused on the left-over costs from the California energy crisis – particularly the above-market or "stranded" costs associated with the long-term, high-priced power contracts that the state's Department of Water Resources (DWR) signed during the crisis. These costs are now included in IOU electric rates, and are expected to decline to zero by 2011 as the DWR contracts gradually expire over the next seven years.

Our analysis indicates that the potential magnitude of any such "cost shift" will be small, if there is any shift at all, and far less than the offsetting energy, environmental, and economic benefits. This is because the costs that the utilities will avoid through the development of a broad market for solar in California are close in magnitude to the current level of retail electric rates in the state for residential and commercial customers. Figure X compares the solar avoided costs produced by the E3 model to the model's assumed weighted average of

[51] See, for example, "Solar initiative has a dark side" by Professor Severin Borenstein (originally published in the San Jose Mercury News), available at http://faculty.haas.berkeley.edu/borenste/sjmerc040820.pdf.

residential and commercial retail electric rates. The solar avoided costs are almost 80% of current and expected retail electric rates.[52] This indicates that the revenues that the IOUs lose as customers switch to their own solar generation will be largely offset by the costs savings that the IOUs realize from not having to serve those customers. We expect that any cost shift in IOU electric rates as a result of the Million Solar Systems program will be only $300 million over the initial ten years of the program. From the perspective of equitably sharing the costs of the energy crisis, by the time that substantial numbers of solar users are on the system in the 2008 – 2011 time period, most of the energy crisis costs will have been paid.

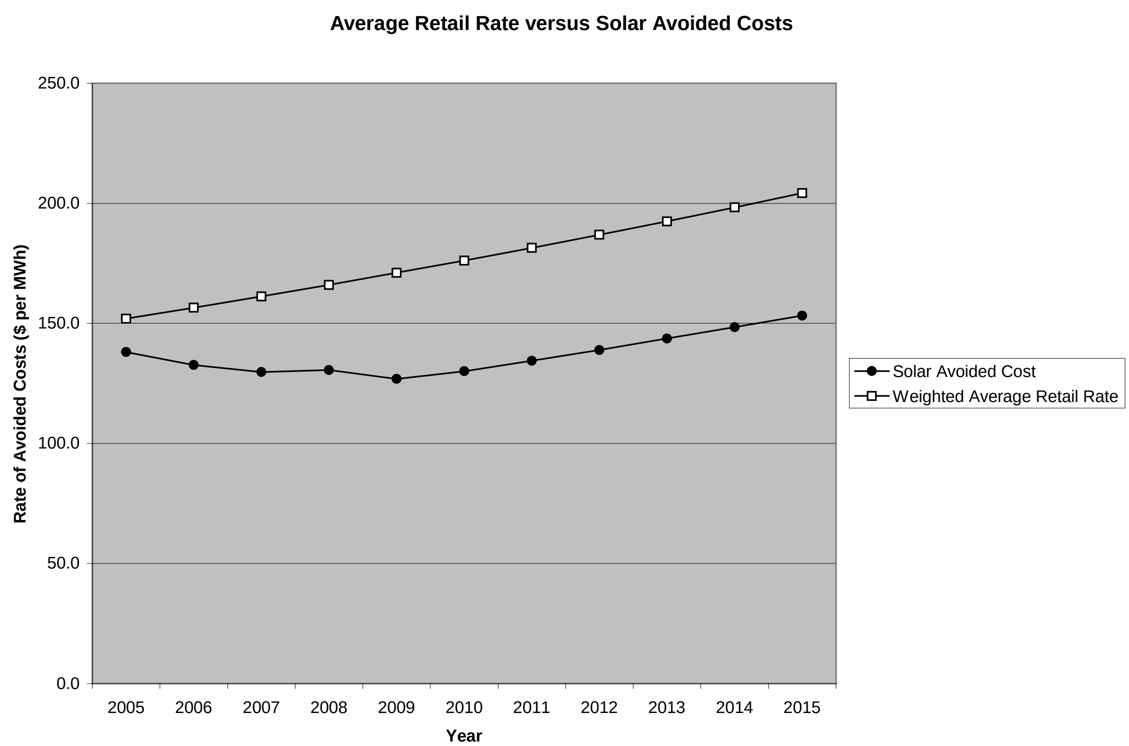


Figure X

Many customers that choose solar also install time-of-use meters and take service under TOU rate schedules. Our model assumes that 50% of residential customers choose TOU meters and rate schedules.[53] In combination with net metering, TOU metering can increase the

[52] Our model assumes that retail rates escalate at a constant 3% per year. A more detailed model of future utility rates could show the impact of natural gas prices and the expiration of the DWR contracts. Such a more detailed model would be likely to reduce our retail rate forecast, particularly in the 2008 to 2012 period as the DWR contracts expire, and thus would produce an even closer comparison with our projection of solar avoided costs.

[53] It is important to be aware that most customers that choose solar do not have TOU meters prior to installing solar. As a result, the revenues that the IOU will lose from a customer producing his or her own power should be based on the average non-TOU retail rate that the typical customer paid prior to installing solar. This is the comparison presented in Figure 3.

economic benefits of solar, as solar users are credited at a higher rate for the net on-peak kWh that they produce, compared to the net off-peak kWh that they consume. The utilities have expressed concern that net metering on TOU rate schedules results in an additional cost shift to solar users from remaining ratepayers. However, this concern can be alleviated if TOU rates are designed carefully to be revenue-neutral compared to non-TOU rates. In addition, solar users who choose TOU rate schedules are given a very strong economic incentive to shift their usage out of the summer on-peak period, in order to maximize their on-peak net generation. This shift in loads produces additional energy efficiency benefits for the IOUs that are not captured in our model, and will tend to offset any adverse cost shift from poorly designed TOU rates. Although the interaction of solar generation, TOU rates, and net metering is a complex area that deserves further study – and perhaps adjustments by the CPUC in the design of TOU rates -- we do not anticipate a significant "cost shift" as a result of the availability of TOU rates to solar users.

Finally, it is important to note that solar adopters are also incurring costs in their purchase of the systems. While incentives do reduce the cost of these systems, customers nevertheless must invest a significant amount of money to install them. It is reasonable to argue that a more comprehensive assessment of the cost of California's energy crisis should also include the costs of reducing the state's reliance on out-of-state sources of energy. From this perspective, any shifting away of stranded costs is less than the total expected investment that will be made by customers installing solar, estimated by the *Million Solar Systems Model* to be over $3 billion over the ten years of the program.[54]

Public Policy Benefits

Providing purchase incentives to stimulate the solar market makes good policy sense as well. Quantifiable benefits received by the state surpass expenditures on incentives within a few years of full-scale adoption – resulting in reliable and positive return on funds invested.

The state also benefits by leveraging private investment. Rather than the sate or ratepayers at large funding the full development cost of new energy facilities, providing incentives for solar encourages private citizens to invest their own resources for the overall public good.

Summary

Accepted modeling methods demonstrate that widespread adoption of solar energy technology, as envisioned in the Million Solar Systems Initiative, will yield dramatic net benefits to California:

- 3,200 megawatts of peak generating capacity worth $6 billion in avoided infrastructure costs
- 273 million therms of thermal generating capacity offsetting natural gas and electric usage
- $661 million in environmental benefits, including reduced greenhouse gases

[54] Million Solar Systems Model, sum of annual customer investment, 2005-2016, in 2005 $.

- $2.6 billion contributed to the state's economy in terms of permanent jobs and tax revenues
- $9.6 billion in customer fuel savings

6. The Million Solar Systems Model

Model Objectives

Incentives have become an established policy tool to spur development of markets that would benefit the state in an overall fashion. However, from the state's overall perspective it is desirable to set incentives so that the benefits of the program are greater than the costs. The *Million Solar Systems Model* attempts to realistically determine the overall costs-benefit equation for solar by quantifying all the costs and benefits for individual systems.

Once these costs and benefits have been determined, then real world customer purchase behavior is used to determine overall industry growth – and therefore the net (after incentive) costs and benefits. Although we have seen other modeling techniques used to determine certain costs and benefits, we believe this model is unique in objectively quantifying all of the costs and benefits for the state and then applying these results to the customer's demand curve.

The *Million Solar Systems Mode*l is, we believe, the most comprehensive attempt to date to utilize market data to analyze and predict end-customer behavior at different incentive levels. This model will evolve over time as more data becomes available and we are able to fine-tune the model's parameters to meet the state's policy needs.

Key Assumptions

Since the model is based on real-world purchasing behavior, using accurate customer-side data is absolutely critical.

Data sources for system costs, system sizes and market data are shown in Appendix 1.

Performance modeling of PV systems was based on techniques developed at Endecon Engineering applied to San Jose weather and electrical data. Results of this model compare favorably to results for comparable systems that were evaluated in a recent CEC study of residential PV systems.[55]

Ongoing maintenance and component replacement are factors that cannot be ignored. Since there was no reliable data source for component replacement costs we made the assumption that all major components (modules, panels, inverters and pumps) would have a lifespan of twice their manufacturer warranty period. At the end of this lifespan these components would have to be replaced. There is no performance deterioration, and at the end of the equipment lifespan the salvage value is assumed be zero (these two factors tend to balance out).

[55] "Measured Performance of California Buydown Program Residential PV Systems, 2000-2001," www.energy.ca.gov/renewables/emerging_renewables.html

Equipment warranty, expected lifespan and estimated annual system maintenance costs are shown in Appendix 1.

The economic assumptions used throughout this analysis are shown in Appendix 1.

Incentives are net to the customer and include applicable federal tax credits and depreciation benefits. We have assumed that the existing 7.5% California state tax credits will be extended for the duration of this analysis.

Model Methodology

Model Overview

The *Million Solar Systems Model* uses the following process to determine the net benefits of solar to the state.

1. Costs and benefits in each market segment were calculated without incentives. NPV, cash breakeven, IRR and simple payback were calculated for each segment

2. An effective demand curve was created using historical data (primarily from California but also considering New Jersey, Japan and Germany). This demand curve was corrected for observed product diffusion effects.

3. Segment growth rates were determined to achieve the goal of one million solar system equivalents by the end of 2015.

4. Growth rates were then applied to the existing installed base to ramp up to the goal of one million solar systems.

5. Annual customer, energy, environmental and economic savings were calculated.

6. Net customer system costs (considering incentives) were calculated based on annual installations and annual system costs using future annual system costs based on the learning curve.

7. Net incentives provided by the state were calculated by subtracting the total market costs from the net customer system costs.

8. With these incentives, NPV, cash breakeven, IRR and simple payback are calculated for each segment.

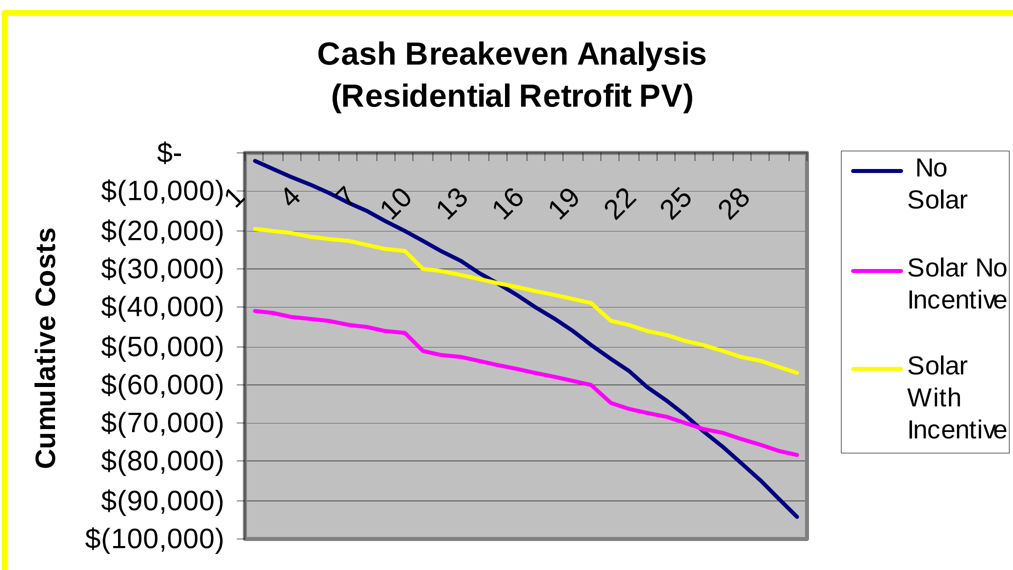
9. Net benefits to the state were calculated by subtracting annual savings from annual incentive costs.

The methodology used to compute the economics of solar is based on the technical specifications of each examined market segment: PV retrofit, PV new construction, PV commercial, PV government, DHW electric retrofit, DHW gas retrofit, DHW electric new, DHW gas new, and pool. The underlying premise of the methodology is that investments in solar reduce the energy bill of consumers (either for electricity or gas). This energy bill savings is computed for each year by multiplying the energy savings from the solar installation by the assumed electricity or natural gas price.

These energy bill savings can be thought of as a positive cash flow over the lifetime of the solar investment. The solar investments are assumed to be financed with a loan, as is typical for solar customers. This gives a negative cash flow over the loan term. For most market segments, this is partly offset by the positive cash flow of a tax savings, either from the mortgage tax deduction or commercial depreciation of investments. This tax savings decreases over time, as the loan principal is paid off or the investment is fully depreciated. There is also a second negative annual cash flow from the maintenance costs incurred to keep the solar system in working order. These factors represent the core of the analysis and the net annual cash flow provides a Net Present Value estimate for each market segment, based on an assumed discount rate.

In addition to the Net Present Value, we also compute the simple payback, cash breakeven point and an Internal Rate of Return. The simple payback in years is the initial cost of the system divided by the first year annual energy savings. Although simplistic we believe this metric is commonly used by California homeowners, particularly since the result is straightforward and fairly accurate for timeframes corresponding to the average tenure of homeownership (seven years).

The cash breakeven point is calculated by finding the year in which the cumulative negative cash flows resulting from energy payments without solar is equal to the cumulative cash flows resulting from lower energy payments (and higher maintenance costs) after the initial cash installation investment. This cash breakeven point is a good, intuitive metric for determining how the two scenarios – solar and no solar – compare. For example, the graph below shows the cash breakeven for a residential retrofit PV system (note the jogs in the curves corresponding to inverter replacement in years 10 and 20) based on assumed incentives as described in Section 7.



The Internal Rate of Return is calculated by using a series of cash flows put together as follows: first, adjust the installation cost by the tax savings, and use this adjusted measure as the initial negative capital outlay that provides the positive cash flows of the utility bill savings minus the maintenance costs for the lifetime of the investment.

This same general analysis is done with and without state incentives, to provide insight into the role of state incentives in the economics of each market segment. For the purposes of this analysis, state incentives are assumed to decline on a per unit basis to reach zero by 2015 so that in 2016 the market continues to grow without incentives.

Methodology by Market Segment

Pool Solar

Pool solar array size, total installation cost, and gas boiler efficiency are input parameters, primarily based on data from Heliocoil. From these, the annual gas savings (in therms) due to the solar installation is computed. The analysis is done for the expected 20-year lifespan of the collectors. Assumptions for this pool solar analysis are shown in Appendix 1.

Domestic Hot Water – Gas Systems

This description applies to both DHW gas retrofit and DHW gas for new construction. For DHW natural gas systems, the array size, total installation cost, gas savings (in therms), and total natural gas use are all input parameters, based primarily on data from SunEarth, Inc. The analysis is done for the expected 20-year lifespan of the collectors. Appendix 1 shows the assumptions for these DHW gas retrofit and DHW gas new construction systems.

Domestic Hot Water – Electric Systems

This description applies to both DHW electric retrofit and DHW electric for new construction. For DHW electric systems, the array size, total installation cost, electricity savings (in kWh), and total electricity use are all assumed, again based primarily on data from SunEarth, Inc. The analysis is done for the expected 20-year lifespan of the collectors. Appendix 1 shows the assumptions for these DHW electric retrofit and DHW electric new construction analyses.

PV Ratings Adjustments

PV system size figures in this report are based on nameplate DC ratings (or peak DC ratings) since these peak ratings are used more commonly within the industry to gauge capacity, these ratings are easy to calculate, and these ratings are easier to compare to different state and country PV programs. Peak DC ratings are typically 20% higher than CEC ratings for comparable systems. Peak DC watt ratings of systems are calculated by multiplying the total number of PV modules by the nameplate rating (also referred to as the Standard Test Conditions rating) of each module. For example, a system using 18 PV modules, each with a STC rating of 167 watts would have a peak DC rating of 3006 DC watts.

The CEC rating for the same system is calculated by multiplying the total number of PV modules by the PTC (PVUSA Test Conditions) rating of each module, then multiplying by the inverter efficiency (up to the maximum output of the inverter). In the example above, 18 PV modules each with a PTC rating of 149.6 watts (167 STC) and a 2500 watt AC inverter with a 94% efficiency would have a CEC rating of 2531 watts – but then would be capped at 2500 watts which is the maximum output of the inverter. In this example the CEC rating is 20% less than the peak DC rating of the system.

PV Government

Government facilities are not able to take advantage of the tax savings from these investments. Therefore, state and federal tax credits – as well as accelerated depreciation – do not provide any additional investment benefits (although these benefits could be made to flow through to an independent entity that could purchase the system and lease it back to the government customer). The analysis is done for 30 years. Appendix 1 shows the assumptions for this government PV analysis.

PV Commercial

The analysis of PV Commercial systems is similar to PV Government, but the average system size is smaller and there are large depreciation tax savings from depreciating the investment. Appendix 1 shows the assumptions for this commercial PV analysis.

PV Residential Retrofit and New Construction

Appendix 1 shows the assumptions for these residential PV analyses.

Market Segment Summaries

It can be a contentious issue to compare different solar technologies and market segments to each other. Nevertheless, it is the opinion of the authors of this study that objective comparisons are necessary by the state to allocate resources – and also by the solar industry itself to identify market trends and investment opportunities. The cross-market segment analyses we have done in this report are based on a consistent set of economic data, consistent performance analyses and current market based pricing data.

The table below summarizes the economic assumptions used in these comparisons.

Comparison Table Between Market Segments

	System Size (DC watts or ft^2)	Installation Cost (thousands of dollars)	Loan Term /Lifespan (years)	Tax Savings	Additional Maintenance Costs (# replace)
Pool	325	3.4	20	mortgage	none
DHW Gas New	64	3.4	20	mortgage	pump (1)
DHW Gas Ret	64	4.2	20	mortgage	pump (1)
DHW Elec. New	64	4.0	20	mortgage	pump (1)
DHW Elec. Retrofit	64	4.2	20	mortgage	inverter (2)
PV Government	200,000	1,394	30	none	inverter (2)
PV Commercial	100,000	697	30	mort & dep	inverter (2)
PV Res. New	2,102	14.9	30	mortgage	inverter (2)
PV Res. Retrofit	5,520	40.2	30	mortgage	inverter (2)

The fundamental principle of the analyses in this report is that customers on the average make rational buying decisions based on realistic economic data. However, the metric by which customers makes buying decisions varies by market segment and customer sophistication. It is worth emphasizing that there is no one single metric used by customers across all these market segments. Although NPV is perhaps the most financially rigorous metric and is evaluated by commercial customers, it is not very commonly used for residential buying decisions -- even when the NPV is presented and explained to the customer. In our experience *simple payback is the most commonly used metric* for residential customers.

The table below summarizes some of the more common economic metrics used by customers. Note that for the NPV and IRR analyses financing costs are taken into account; for the Cash Breakeven and Simple Payback analyses financing costs are not considered. The metrics in this table are calculated without incentives.

Market Segment Summary - No Incentives

Market Segment	Price	Size (DC watts or ft^2)	yr 1 Savings $/yr	Savings kwh/yr or therms/yr	NPV	Cash Break Even	IRR	Simple Payback	Annual Net Cash Flow
PV Res Ret	$40,204	5,520	$1,330	7,176	($8,870)	25.00	4.1%	30.2	($828)
PV Res New	$14,927	2,102	$507	2,733	$1,047	7.00	8.4%	29.5	($301)
PV Commercial	$627,300	100,000	$16,686	120,000	($149,077)	22.00	3.1%	37.6	($46,256)
PV Govt	$1,394,000	200,000	$33,372	240,000	($664,575)	30.00	1.0%	41.8	($130,228)
DHW Elect Ret	$4,200	64.0	$575	3,100	$4,080	7.00	18.9%	7.3	$269
DHW Gas Ret	$4,200	64.0	$161	130	($1,440)	20.00	1.1%	26.1	($145)
DHW Elect New	$3,360	64.0	$575	3,100	$4,733	6.00	23.6%	5.8	$326
DHW Gas New	$3,360	64.0	$161	130	($787)	20.00	3.2%	20.9	($88)
Pool	$4,000	325.0	$1,060	858	$10,818	4.00	36.4%	3.8	$769

Incentives are used to improve these customer metrics. In the table below these metrics are summarized by market segment after incentives are applied. The basis on which these incentives were calculated is discussed in more detail in Section 7.

Market Segment Summary - With Incentives

Market Segment	Price	Incentive	Price with Incentive	NPV with Incentive	CB with Incentive	IRR	Simple Payback	Annual Net Cash Flow
PV Res Ret	$40,204	$21,397	$18,807	$6,373	14.0	10.72%	14.1	$315
PV Res New	$14,927	$7,654	$7,273	$2,173	4.0	10.31%	14.4	$108
PV Commercial	$627,300	$385,275	$280,553	$83,304	13.0	11.14%	16.8	($7,607)
PV Govt	$1,394,000	$720,000	$674,000	($71,743)	19.0	5.87%	20.2	($45,823)
DHW Elect Ret	$4,200	$0	$4,200	$4,080	7.0	18.94%	7.3	$269
DHW Gas Ret	$4,200	$1,280	$2,920	($445)	17.0	4.62%	18.2	($58)
DHW Elect New	$3,360	$0	$3,360	$4,733	6.0	23.58%	5.8	$326
DHW Gas New	$3,360	$1,280	$2,080	$207	14.0	8.43%	12.9	($1)
Pool	$4,000	$0	$4,000	$10,818	4.0	36.41%	3.8	$769

Growth Rates and Demand Elasticity

Growth Rates

To meet the objective of one million solar systems by 2015, the *Million Solar Systems Model* uses a path of growth rates that can reasonably be expected based on existing market segment sizes and current incentive levels. The average growth rate in each market segment from 2004 to 2016 is summarized below.

Growth Rate	
Market Segment	Average 2004-016
PV Res Ret	32.6%
PV Res New	59.2%
PV Commercial	29.0%
PV Government	32.8%
DHW Ret Electric	183.4%
DHW Ret Gas	43.3%
DHW New Electric	192.7%
DHW New Gas	53.7%
Pool	1.7%

Note that for certain stable markets (such as pool solar) the growth rate is relatively small, although the units sold in each year are substantial. For new markets in which the installation infrastructure can be ramped up quickly and technology is relatively mature (such as DHW) the growth rates can be very high. Growth rates for the PV market segments are limited both by availability of equipment (modules and inverters) and available installation infrastructure. Because of these two factors in the PV segments extremely high market growth rates are not practical; 30% to 60% growth rates are rapid but realistic.

Methodology for Market Growth over Time

Mature and unsubsidized markets generally demonstrate increased market growth (expressed as an annual percentage) as customer prices decline. However, solar markets are still in their infancy with many early customers making their purchase decision based on non-economic factors – primarily environmental benefits. Moreover, as described above, the economic purchasing decision is based on lifecycle costs, incentives and ongoing energy savings. As a result of the relative infancy of these markets -- coupled with a complicated incentive picture -- it has been difficult to determine demand elasticity that reflects actual customer behavior.

Another factor possibly masking demand elasticity in the data is the fact that solar technology is only now becoming recognized as available to a large portion of the general public.[56] Some of this deficiency is due to a lack of awareness that solar technologies are affordable and practical to the general public, and some is due to the lack of awareness of incentives. In either case, this lack of public awareness could result in an insufficient pool of potential customers available to purchase as effective prices fall. This possibility suggests that a portion of incentive program resources might be well spent if directed toward promoting the program itself

We model costs and market growth over time based on three main factors: a learning curve, a demand curve, and assumed market diffusion.

Learning Curve

Learning curves are commonly used in newly developing markets to model how the price of an item decreases as manufacturers' gain experience producing or installing the item. For solar, this could involve more efficient installation practices discovered through trial and error, as well as improved manufacturing processes for solar systems. Essentially, as more solar systems are installed, the total installation price declines.

To model this behavior, we use the standard learning equation, as used in many market analyses[57]. We base this learning curve on data from the Japanese PV market, which implies a Progress Ratio in the range of 0.8 for PV systems. The Progress Ratio is lowered to 0.78 for DHW systems to reflect the fact that current relatively high prices are based more on market infrastructure limits (there are currently few contractors and minimal economies of scale within the DHW installation industry) than equipment prices. Note that low Progress Ratios imply a faster price reduction.

We use this learning curve to give us an installation cost in each year, which is based on the number of installed systems in the previous year.

Demand Curve

Given the installation cost, the quantity of each type of solar system is solved for based on a demand curve. This demand curve (or in other words, the price elasticity of demand) is derived directly from CEC data on the PV market from the last five years. Specifically, we fit a logarithmic demand curve to the CEC data. We modify this demand curve to match recent sales estimates and to better fit each market segment.

Market Diffusion

Since solar is the early stages of market penetration, the CEC data exhibits growth that has been limited by the rate of market diffusion. To account for faster diffusion as the market

[56] "Solar Dealers 2004," Coast Hills Partners
[57] "Clean Energy Buydowns: Economic Theory, Analytic Tools and the Photovoltaic Case," Richard D. Duke

expands and customers become informed about solar systems, we have an additional parameter that increases the annual number of systems installed by a specified percentage of the previous year's installations (which can be varied).

7. Million Solar Systems Model Results

Summary Results: Solar Benefits Outweigh Costs

As shown in the table below, the benefits that Distributed Generation solar will provide to California significantly outweigh the necessary incentive costs. Moreover, the fact that these benefits accrue from multiple sources – including customers, energy infrastructure, the environment and our overall economy – even if the quantifiable contributions from one source are limited or questionable the overall benefits to the state are still quite positive.

Benefits Summary (million 2005 dollars)	**Total 2006-2015**
Customer Savings	$ 9,631.1
Energy Infrastructure	$ 6,036.1
Economy (Jobs & Tax)	$ 2,613.4
Environment	$ 661.1
Total	$ 9,310.6
Incentive Costs	$ (2,892.6)
Net Benefits to State	$ 6,418.0
Installed PV Capacity (MW)	3,247
Installed Thermal Capacity (MM Therms)	273

Model Findings

One of the most useful findings of the model is that it reasonably predicts market segment behavior under changing conditions – particularly changes to incentive levels and customer system costs. As the state considers changing the amount of funding directed towards each market segment it is absolutely critical that the there is an understanding of how these changes affect the growth in each market segment.

Earlier versions of this model did not include algorithms to model customer purchasing behavior. When these algorithms were added it was apparent that achieving the Million Solar Systems goal would require funding in excess of that predicted by Cal SEIA[58] and others –

[58] "Solar Vision" California Solar Energy Industries Association

even when all the solar thermal market segments were included. Since these algorithms are so important to the model we will continue to fine-tune them as the details of the Million Solar Systems program are finalized.

Incentive Funding Determines Market Growth

The amount of incentive funding required to achieve one million solar systems is defined by customer behavior as expressed in the overall demand curve. In other words, once the goal (one million systems) and the duration (ten years) are set, customer demand will generate the necessary sales. The only significant variable is the state's ability to modify effective customer price with incentives (such as rebates and tax credits).

Assuming a level of funding that does not take into account this demand curve will almost definitely result in fewer systems being installed within the ten-year timeframe.

Incentives are used as the primary tool to modify customer behavior – and thus segment growth rates. However incentives only direct affect the Demand Curve (as prices are reduced more people will purchase). Incentives do not directly affect the Learning Curve (prices naturally because of economies of scale as more systems are installed) nor do they affect Market Diffusion (more customers purchase systems because their neighbors already have).

Incentives by Segment

The methodology developed in the *Million Solar Systems Model* can set incentives in each market segment to achieve a target customer buying threshold. These incentives would then decline over time based on estimates of the customer's demand curve for solar systems and are reduced to zero after a ten-year program. The mechanism by which these incentives are offered to customers – as a rebate, tax credit, or production credit, or combination thereof – is not addressed in this analysis.

Since these are the net incentives required for the customer to make a buying decision, external incentives not included in this model must be factored in. For example, if the pending $2,000 Federal Solar Tax Credit for solar systems goes into effect in 2006, then this credit would commensurately reduce the amount of incentive provided by the state. By the same token, changes in energy prices or equipment costs in excess of those calculated within the model (based on the Learning Curve) would require an adjustment in the incentive.

The following table summarizes the incentives we used as a *starting point* in each market segment to achieve the Million Solar Systems goal. For PV systems these incentives are similar to those in existing CEC and SelfGen programs. For DHW systems these incentives are those that we expect will "jump start" the market again in an effort to restore it to the growth rates experienced in the 1980s. No incentives are necessary for the pool and DHW electric new market segments.

Incentives

	CEC	DC
PV Residential Retrofit ($/watt)	$ 3.00	$ 3.60
PV Residential New Construction	$ 2.80	$ 3.36
PV Commercial	$ 3.00	$ 3.60
PV Govt	$ 3.00	$ 3.60
DHW Electric Ret ($/ft2)	$ 20.00	$ 20.00
DHW Gas Ret ($/ft2)	$ 20.00	$ 20.00
DHW Electric New ($/ft2)	$ -	$ -
DHW Gas New ($/ft2)	$ 20.00	$ 20.00
Pool ($/ft2)	$ -	$ -

Segment Results

There are several interesting results of the model that merit further explanation:

- Pool solar systems are already very cost effective, contribute greatly to the state's savings, and therefore do not require any incentives at all to continue on a robust growth path. This market should continue to be encouraged, but does not require incentive funding.

- Since the market for DHW systems is virtually negligible, there are great improvements to be had in installation efficiency and market awareness. Therefore, we recommend that incentives be used initially to get the DHW market re-started and operating in a scalable and efficient fashion. Initial costs for DHW systems are inordinately high because the qualified base of installation contractors has dwindled. The model expects that installation costs for DHW systems will be restored to that of the early '80s when the market was much larger. It is also reasonable to expect to see the necessity for larger incentives for natural gas fired systems compared to electric (or propane) since energy costs are so much greater for electric systems. Less tangible risk avoidance benefits from supporting the DHW market are important – the state uses a large amount of natural gas to heat water (either directly or indirectly with electric water heaters), and having a large installed base of solar DHW systems will reduce our dependence on this increasingly scarce resource.

- Government systems require higher incentives than commercial systems because of the inapplicability (or limited applicability) of tax credits and depreciation. Moreover, costs are structurally higher because of prevailing wage requirements. Third party financing techniques and shared savings programs can enable a corporate entity to benefit from these tax savings – thereby making overall government system economics closer to those for corporate customers. However, the decision to install a government system is generally more of a policy decision than a purely economic decision. Since the market for large systems is still quite small and there are relatively few companies that are qualified to deliver these systems, there may not be the same competitive pressure to reduce price as experienced in other segments.

- Note that this report assumes that new homebuilders can offer thermal or PV systems, or both. There is not a great difference between retrofit and new construction system costs – primarily because the potential economies of scale for new construction are outweighed by smaller system sizes and obscure (to the home purchaser) customer economics. For this segment to be open and competitive it is important that customers understand the fair value of the solar system being offered to them – otherwise there is the possibility that homebuilders or salespeople would reap windfall profits from the "optional" installation of solar systems on new homes.

- PV commercial and PV residential retrofit markets are the most established and provide the most certainty in required incentive levels, growth rates and net state benefits. There is a high degree of certainty that these segments will contribute to future state benefits as modeled in this report.

- In this modeling process, we did not try to optimize across segments in terms of relative level of incentives. It is our position that, given a level playing field, market forces will reveal winning solar technologies through inherent customer adoption levels over time

Sensitivity Analysis & Alternative Scenarios

Sensitivity Analyses on Model

One of the biggest challenges for policy makers is determining on how changes to solar incentive programs affect the market and overall program goals. By basing the *Million Solar Systems Model* on customer purchase behavior, changes to program goals – such as total systems installed or total dollar benefits to the state – can be determined by changing assumptions. The results of several of these sensitivity analyses are described below.

Alternative Scenario: Prevailing Wage Rates

Since direct rebates are provided by the state, there is the perspective that these state contributions would require that all work on solar systems that receive a state incentive be done at prevailing wage rates (generally union wages for electrical contractors). To evaluate the effect of prevailing wages we assumed that installation costs would increase by 20% in all but the commercial and government market segment (which are already installed at prevailing wage rates).

Because these prevailing wage rates effectively increase the cost of the system to customers, greater state incentives would be required to achieve the Million Solar Systems goal – or many fewer systems would be installed under the same planned level of incentives and growth rates.

If solar costs were raised by 20% in all but the government and commercial segments, net benefits to the state would be reduced by $1.7 billion dollars and the total number of systems installed would be reduced by approximately 200,000. Alternatively, in the new construction market in which the entire cost of the home would possibly be increased by 20%, solar would be completely non-cost effective in these market segments and this entire segment would be eliminated. If the new construction market were excluded because of this drastic home cost increase, net benefits to the state would be reduced by a further $1.3 billion dollars and the total number of systems installed would be reduced by an additional 120,000.

Alternative Scenario: Limited Incentives Fund to $1B

The total amount of incentive dollars presented in this report was calculated based on existing market sizes, equipment costs, savings and demonstrated customer purchasing behavior. If incentives were reduced to a total of $1 billion over ten years, the implication to customers would be that costs are higher, thereby reducing purchases and net benefits to the state. The effects of applying $1 billion of incentive funding over ten years would be that 760,000 solar systems would be installed (instead of one million systems – and approximately 50% being solar thermal) and the state's benefits would be reduced to $3.8 billion (net of incentives but not including direct customer benefits).

Alternative Scenario: Remain with Current Incentives (identifies opportunity cost of doing nothing)

California's current solar incentive program includes a $3.00/watt rebate for small systems (with a declining schedule of $0.20/watt every six months), a $4.50/watt rebate for large systems and a 7.5% state tax credit that will expire on 12/31/05. There are currently no incentives for solar thermal systems. If incentives were continued on this declining schedule and if commercial/government incentives were set to the same level as residential systems, net benefits to the state would be $3.6 billion (net of incentives but not including direct customer benefits), incentive costs would be $559 million and the total number of systems installed by the end of 2015 would be 690,000 – 61% of which would be solar thermal systems.

Alternative Scenario: Set Incentives so that Net Annual Cash Flow is Zero

The table below shows the necessary incentives in each market segment so that the net annual cash flow to the customer is zero. At this level of incentive funding a customer should theoretically be neutral in terms of a buying decision based on considering monthly cash payments, financing effects and tax effects. Negative values for DHW electric and pool systems imply that no incentives are needed. It is the opinion of the authors that incentives set at these levels will not result in the rapid market growth needed to achieve the Million Solar Systems goal.

Incentives	**CEC $/watt**	**DC $/watt**	**Annual Net Cash Flow**
PV Residential Retrofit ($/watt)	$ 2.04	$ 2.44	$0
PV Residential New Construction	$ 1.93	$ 2.32	$0
PV Commercial	$ 3.85	$ 4.62	$0
PV Govt	$ 4.63	$ 5.55	($0)
DHW Electric Ret ($/ft2)	$ (61.87)	$ (61.87)	$0
DHW Gas Ret ($/ft2)	$ 33.29	$ 33.29	$0
DHW Electric New ($/ft2)	$ (75.00)	$ (75.00)	$0
DHW Gas New ($/ft2)	$ 20.17	$ 20.17	($0)
Pool ($/ft2)	$ (34.78)	$ (34.78)	($0)

Alternative Scenario: Set Incentives for Targeted Cash Breakeven

The table below shows the necessary incentives in each market segment so that the cash breakeven to the customer is seven years for consumer market segments and five years for commercial and government customer segments. Seven years was selected for consumer segments since this is the average duration of home ownership; a shorter time period was selected for commercial and government segments since they typically have a shorter planning horizon. Low incentive values for residential new construction systems imply that the cash breakeven is already close to seven years without incentives – primarily because the amount of energy provided by these smaller systems is relatively modest compared to overall home energy consumption (i.e. the systems are undersized for the home). Negative values for DHW electric and pool systems imply that no incentives are needed.

Incentives	**CEC $/watt**	**DC $/watt**	**Cash Breakeven**
PV Residential Retrofit ($/watt)	$ 4.52	$ 5.42	7.00
PV Residential New Construction	$ 0.11	$ 0.13	7.00
PV Commercial	$ 4.71	$ 5.65	5.00
PV Govt	$ 5.14	$ 6.17	5.00
DHW Electric Ret ($/ft2)	$ (0.66)	$ (0.66)	7.00
DHW Gas Ret ($/ft2)	$ 50.19	$ 50.19	7.00
DHW Electric New ($/ft2)	$ (10.66)	$ (10.66)	7.00
DHW Gas New ($/ft2)	$ 36.10	$ 36.10	7.00
Pool ($/ft2)	$ (9.42)	$ (9.42)	7.00

Alternative Scenario: Set Incentives for Targeted Simple Payback

The table below shows the necessary incentives in each market segment so that the simple payback to the customer is seven years for consumer market segments and five years for commercial and government customer segments. Based on selling efforts to literally thousands of residential customers, it is the opinion of the authors that simple payback is the most commonly used metric – even though it is not as financially rigorous as NPV.

Seven years was selected for consumer segments since this is the average duration of home ownership; a shorter time period was selected for commercial and government segments since they typically have a shorter planning horizon. Negative values for DHW electric new and pool systems imply that no incentives are needed.

Incentives	CEC $/watt	DC $/watt	Simple Payback
PV Residential Retrofit ($/watt)	$ 4.55	$ 5.46	7.00
PV Residential New Construction	$ 4.40	$ 5.28	7.00
PV Commercial	$ 4.97	$ 5.97	5.00
PV Govt	$ 5.11	$ 6.14	5.00
DHW Electric Ret ($/ft2)	$ 2.76	$ 2.76	7.00
DHW Gas Ret ($/ft2)	$ 48.05	$ 48.05	7.00
DHW Electric New ($/ft2)	$ (10.36)	$ (10.36)	7.00
DHW Gas New ($/ft2)	$ 34.93	$ 34.93	7.00
Pool ($/ft2)	$ (10.53)	$ (10.53)	7.00

Alternative Scenario: Set Incentives for Zero NPV

The table below shows the necessary incentives in each market segment so that the net present value (NPV) to the customer is zero. At this level of incentive funding a customer should theoretically be neutral in terms of a buying decision based on considering all relevant financing effects, including alternative investments. Negative values for DHW electric new and pool systems imply that no incentives are needed. It is the opinion of the authors that incentives set at these levels will not result in the rapid market growth needed to achieve the Million Solar Systems goal.

Incentives	CEC $/watt	DC $/watt	NPV
PV Residential Retrofit ($/watt)	$ 1.54	$ 1.85	$0
PV Residential New Construction	$ 1.49	$ 1.79	$0
PV Commercial	$ 1.51	$ 1.81	$0
PV Govt	$ 3.36	$ 4.04	$0
DHW Electric Ret ($/ft2)	$ (82.05)	$ (82.05)	($0)
DHW Gas Ret ($/ft2)	$ 28.96	$ 28.96	($0)
DHW Electric New ($/ft2)	$ (95.17)	$ (95.17)	$0
DHW Gas New ($/ft2)	$ 15.83	$ 15.83	$0
Pool ($/ft2)	$ (42.84)	$ (42.84)	$0

8. Recommendations

Based on our understanding of the real world dynamics of the solar industry, evaluations of other solar programs as well as detailed analysis of market-based solar industry data, we have the following recommendations:

Include both solar electric and solar thermal

Providing customers with a choice of technology will facilitate their buying decision and allow systems to be installed in a wider range of applications – particularly where roof space is constrained. In addition, as shown in the graph of cumulative systems below, these thermal technologies will account for roughly 50% of the entire million systems – reducing the amount of incentive funding required for the program as a whole

Structure incentives and related public policy to drive customer purchases based on actual market conditions and accurate historical data.

Incentive levels recommended in this report are higher than those proposed in other studies. There are two reasons for this. First, the goal of one million solar systems is ambitious and greater than that originally evaluated by industry groups. Second, this report bases system installation growth on customer purchasing behavior, market diffusion factors and product learning curves – instead of a linear decline in incentives and system costs. Nevertheless, the benefits to the state are commensurately greater and will do more to alleviate our short-term energy shortages.

Establish predictable, consistent incentives that change with market conditions.

Variations in life cycle costs, third party incentives (including RECs) and energy prices have an enormous impact on customer buying behavior. Predictability in incentive levels is absolutely critical to allow the solar manufacturing and installation industry to make long-term investments that are necessary to drive costs down. Existing CEC and SelfGen programs have been effective to date. In addition, we recommend a public relations campaign – similar to the Flex Your Power campaign – to further stimulate customer awareness of the favorable economics for solar.

Use an analytical tool such as the *Million Solar Systems Model* to fully evaluate solar net benefits and costs in the context of real-world customer behavior.

Customer economic behavior drives the solar market. Therefore, all policy and regulatory programs must be evaluated in terms of how they affect customer behavior and therefore market segment growth. Since the solar market is composed of multiple market segments (residential, commercial, government, new construction) and multiple technologies (solar electric and solar thermal), a modeling tool is needed that encompasses all these segments using a consistent set of assumptions and data. Most importantly, this modeling tool must reflect changes in customer behavior over time as costs and other economic factors change.

9. Appendix - Assumptions

Cost and Savings Data Sources

Cost and Savings Data Sources

Residential Retrofit PV costs - CEC data
Residential New Construction PV costs - CEC data
Commercial and Government Costs - CEC, SelfGen and Coast Hills data
PV kwh savings - PV USA models, San Jose, E-1 and A-10
PV kwh TOU savings 25% over std. tiered rates, 1/2 of customers use TOU (12.5% effective rate)
System availability factor 90% residential (15 degree, SE/SW orientation), 5% shade, 4% soiling
System availability factor 89% commercial (flat), no shade, 6% soiling
Residential DHW costs - SunEarth, Sierra Pacific, Solarhart All Valley
Residential DHW savings - SunEarth, Western Renewables, Solahart All Valley
Pool solar costs - Heliocoil, Western Renewables, Solahart All Valley
Pool solar savings - Heliocoil

Warranty and System Longevity

Warranty and System Longevity	
PV Modules	25
PV Inverters	5
DHW System	10
DHW Pumps	5
Equipment lifespan twice manufacturer warranty	

Economic Assumptions

Economic Assumptions	
Discount Rate	7%
Inflation rate (electric and gas)	3%
Residential Marginal Tax Rate	32%
Residential Borrowing Rate	6.0%
Residential Loan Term (yr)	30
DHW Residential Loan Term (yr)	20
Commercial Marginal Tax Rate	30%
Commercial Borrowing Rate	5.0%
Commercial Loan Term (yr)	7
Govt Borrowing Rate	3%
Govt Loan Term (yr)	10
Electric generation cost growth rate	3%
Residential end-use gas cost growth rate	3%
Average Time-Of-Use electric improvement	12.5%
New Construction Discount (DHW only)	20.0%

Pool Solar Assumptions

Assumptions	
Storage Capacity (gallons)	80
Array Size (ft^2)	325.00
Total Installation Cost	$ 4,000
Initial Gas Savings	3.575
Gas Fired Heater Efficiency	0.75
Days per year used	180
Daily Gas Savings (therms)	4.77
First Year Gas Savings (therms)	858
DHW System Warranty	10
DHW Pump Warranty	5
System Expected Life	20
Pump Expected Life	10
pump % of system cost	0.3
Pump Replacement Cost	$ -
Annual Maintenance	$20
Salvage Value	$0

Solar Domestic Hot Water (Gas) Assumptions

DHW Retrofit Using Gas

Assumptions	
Storage Capacity (gallons)	80
Array Size (ft^2)	64.00
Total Installation Cost	$ 4,200
First Year Gas Savings (therms)	130
Current Gas Use No Solar (therm	330
DHW System Warranty	10
DHW Pump Warranty	5
System Expected Life	20
Pump Expected Life	10
pump % of system cost	0.05
Pump Replacement Cost	$ 210
Annual Maintenance	$20
Salvage Value	$0

DHW New Using Gas

Assumptions	
Storage Capacity (gallons)	80
Array Size (ft^2)	64.00
Total Installation Cost	$ 3,360
First Year Gas Savings (therms)	130
Current Gas Use No Solar (therm	330
DHW System Warranty	10
DHW Pump Warranty	5
System Expected Life	20
Pump Expected Life	10
pump % of system cost	0.05
Pump Replacement Cost	$ 210
Annual Maintenance	$20
Salvage Value	$0

Solar Domestic Hot Water (Electric) Assumptions

DHW Retrofit Using Electric

Assumptions	
Storage Capacity (gallons)	80
Array Size (ft^2)	64.00
Total Installation Cost	$ 4,200
First Year kwh Savings	3100
Current kWh Use No Solar	12,000
DHW System Warranty	10
DHW Pump Warranty	5
System Expected Life	20
Pump Expected Life	10
pump % of system cost	0.05
Pump Replacement Cost	$ 210
Annual Maintenance	$20
Salvage Value	$0

DHW New Using Electric

Assumptions	
Storage Capacity (gallons)	80
Array Size (ft^2)	64.00
Total Installation Cost	$ 3,360
First Year kwh Savings	3100
Current kWh Use No Solar	12,000
DHW System Warranty	10
DHW Pump Warranty	5
System Expected Life	20
Pump Expected Life	10
pump % of system cost	0.05
Pump Replacement Cost	$ 210
Annual Maintenance	$20
Salvage Value	$0

PV Commercial and Government Assumptions

PV Commerical Retrofit

Assumptions	
System Size (CEC rated watts)	83,333
CEC to DC conversion	1.2
System Size (DC rated watts)	100000
System Size (modules)	599
Total price per CEC watt	
Total price per DC watt	$6.97
Total Installation Cost	$ 697,000
First Year kwh Savings	120000
Current kWh Use No Solar	300,000
Panel Warranty	25
Inverter Warranty	5
Panel Expected Life	50
Inverter Expected Life	10
Inverter Replacement Cost	$1,800
Number of Inverters needed	30
Total Inverter Cost	$54,000
Annual Maintenance	$181
Salvage Value	$0

PV Government Retrofit

Assumptions	
System Size (CEC rated watts)	83,333
CEC to DC conversion	1.2
System Size (DC rated watts)	200,000
System Size (modules)	1198
Total price per CEC watt	$8.36
Total price per DC watt	$6.97
Total Installation Cost	$1,394,000
First Year kwh Savings	240000
Current kWh Use No Solar	300,000
Panel Warranty	25
Inverter Warranty	5
Panel Expected Life	50
Inverter Expected Life	10
Inverter Replacement Cost	$1,800
Number of Inverters needed	60
Total Inverter Cost	$108,000
Annual Maintenance	$181
Salvage Value	$0

PV Residential Assumptions

PV Residential Retrofit

Assumptions	
System Size (CEC rated watts)	4600
CEC to DC conversion	1.2
System Size (DC rated watts)	5520
System Size (modules)	33
Total price per CEC watt	$8.74
Total price per DC watt	$7.28
Total Installation Cost	$40,204
First Year kwh Savings	7176
Current kWh Use No Solar	12,000
Panel Warranty	25
Inverter Warranty	5
Panel Expected Life	50
Inverter Expected Life	10
Inverter Replacement Cost	$1,800
Number of Inverters needed	2
Total Inverter Cost	$3,600
Annual Maintenance	$10
Salvage Value	$0

PV Residential New Construction

Assumptions	
System Size (CEC rated watts)	1752
CEC to DC conversion	1.2
System Size (DC rated watts)	2102.4
System Size (modules)	13
Total price per CEC watt	$8.52
Total price per DC watt	$7.10
Total Installation Cost	$ 14,927
First Year kwh Savings	2733.12
Current kWh Use No Solar	12,000
Panel Warranty	25
Inverter Warranty	5
Panel Expected Life	50
Inverter Expected Life	10
Inverter Replacement Cost	$1,500
Number of Inverters needed	1
Total Inverter Cost	$1,500
Annual Maintenance	$10
Salvage Value	$0

9. Acknowledgments & Bibliography

Acknowledgments

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Akeena Solar
Akeena Solar is one of the largest national residential and commercial solar electric system installers in the U.S., with offices and full-time installation crews in Los Gatos, CA and Fairfield, NJ. The company provides design/build services so that customers can produce their own reliable and clean electricity directly from the sun. The company's professionals are passionate about the environment and have been in the solar energy field since the 1970s and the last "energy crisis." Akeena's growing list of satisfied customers is a reflection of the care and attention they pay to every installation.

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