Solar PV Retrofits in Multifamily Affordable Housing

Impacts of Virtual Net Metering and MASH Incentives on Project Economics

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Disclaimer

Updates

The authors updated this report with information related to regulatory activities that have taken place since the March 2011 release associated with Virtual Net Metering and the MASH Program per CPUC Rulemaking R. 10-05-004. Additionally, we incorporated findings from several reports that were finalized in recent months, including: Itron's 2010 California Solar Initiative (CSI) Impact Evaluation (June 2011), Navigant Consulting's CSI Low Income Solar Program Evaluation, Market Assessment Report (April 2011), and Energy, Environment, and Economics (E3)'s CSI Cost-Effectiveness Evaluation (April 2011). We also revised text in the report where we identified opportunities for improved clarity.

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Acronyms

AC	Alternating Current
AMI	Area Median Income
CCSE	California Center for Sustainable Energy
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
CUAC	California Utility Allowance Calculator
DC	Direct Current
DOE	US Department of Energy
IOU	Investor-Owned Utility
HUD	US Department of Housing and Urban Development
kW	Kilowatt
kWh	Kilowatt-hour
LCOE	Levelized Cost of Energy
LVOS	Levelized Value of (Utility Bill) Savings
MASH	Multifamily Affordable Solar Housing
MACRS	Modified Accelerated Cost-Recovery Schedule
NEM	Net Energy Metering
NMTC	New Market Tax Credit
NPV	Net Present Value
PG&E	Pacific Gas & Electric Utility
PHA	Public Housing Authority
PPA	Power Purchase Agreement
PV	Photovoltaic
SAC	Solar America Cities
SCE	Southern California Edison Utility
SDG&E	San Diego Gas & Electric Utility
SWH	Solar Water Heating
UA	Utility Allowance
TCAC	Tax Credit Allocation Committee
VNM	Virtual Net Energy Metering

Executive Summary

Introduction

The deployment of distributed solar photovoltaic (PV) systems in California has increased rapidly in recent years. In the last four years (2007-2010), approximately 500 MW of distributed PV capacity has been installed in CA's largest IOUs, over three times the amount installed over the thirteen year period covering 1993- 2006 (~160 MW).[2] This growth has been driven primarily by installations on existing commercial buildings, government facilities, colleges and universities, and single-family residences. PV adoption has been slower in the multifamily (MF) housing sector. To date, a limited number of projects have been completed in the MF *affordable* housing space, led by pioneering property owners who have invested in PV to improve environmental performance, stabilize operating costs, and reduce tenants' electricity bills. These same objectives have motivated policy makers to institute programs that promote the use of PV in affordable housing.

In early 2009, the California Public Utilities Commission (CPUC) launched the Multifamily Affordable Solar Housing (MASH) program, which provides generous incentives for solar PV retrofits in the MF affordable housing sector. In addition, the CPUC required the creation of a new virtual net metering (VNM) tariff to support MASH program growth. VNM addresses one of the biggest challenges of deploying PV retrofit projects in a multitenant setting — the distribution of solar generation credit across multiple separately-metered units. With VNM, a property owner can install one system at a site and distribute the credits "virtually" among tenants, whereas standard net energy metering (NEM) rules require a PV system behind each meter. Having a separate PV system and inverter behind each meter increases overall project costs and can be a barrier to PV development in a multitenant setting.

It was expected that the combination of MASH incentives and VNM would facilitate rapid growth of PV retrofits in the MF affordable housing sector. However, few MASH projects were installed at the outset of the program. Eventually, program activity improved significantly, thanks in large part to the introduction of third-party financing structures such as power purchase agreements (PPAs) and solar leases into the MF affordable housing market.[3] Third party providers were able to leverage substantial MASH incentives and generous tax benefits to offer competitively priced contracts to building owners. Demand for MASH incentives eventually outgrew available funding. At current funding and subscription levels, there will be limited opportunity for affordable housing property owners to access MASH incentives into the future.[4]

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[2] Itron, Inc. 2010. CPUC California Solar Iniatiative 2010 Impact Evaluation Report. Page ES-4.
Itron, Inc. and KEMA, Inc. 2009. CPUC California Solar Initiative 2009 Impact Evaluation Report. Page ES-3

[3] Under a PPA, the PPA provider sells power to the customer on a per kWh basis for a set number of years and is responsible for commissioning, operating and maintaining the PV system performance over the contract term. The PPA provider generally forms either a partnership agreement, a sale/leaseback arrangement. or an inverted or pass-through lease with a third-party tax equity investor (often a bank) who can utilize the tax credits associated with the PV system.

[4] The MASH program was divided into two "tracks". Track 1 incentives are available to all projects that meet program requirements while Track 2 projects were subject to a competitive selection process. Since June 2010, Track 1 projects have been fully subscribed and a number of Track 2 projects have been awarded. A decision issued on July 20, 2011 by the CPUC ordered the program administrators to use remaining Track 2 funds to incentivize projects currently on the wait list for Track 1.[4] If all projects currently on the program administrators' waitlists were to be completed, the majority of remaining Track 2 funds would be exhausted.

While the availability of MASH incentives is currently limited, access to VNM tariffs has recently expanded. In a decision issued in July 2011, the CPUC made significant changes to the scope of virtual net metering tariffs. VNM tariffs had been available only to customers who received MASH incentives. The recent decision directs CA's largest IOUs to make VNM tariffs available to all multi-meter residential, commercial, and industrial properties, regardless of whether or not the customer received a state incentive.[5] MF affordable housing property owners that invest in solar PV will thus be able to utilize virtual net metering tariffs even if they are not able to participate in the MASH program.

The goal of this report is to inform property owners, policy makers and other stakeholders about the project economics of PV in the MF affordable housing space in California. We hope this study will help property owners and tenants make better informed decisions about PV retrofit investments, assist policy makers with decisions regarding incentives and the implications of VNM, and help the public better understand the economic impacts of PV in this sector. This report was produced by the California Center for Sustainable Energy (CCSE) in partnership with the City of San Diego's Environmental Services Department through funding from the Department of Energy's (DOE) Solar America Cities (SAC) Program.

Methods

In this study, we investigated the project economics of PV retrofits in a MF affordable housing setting using a custom-built spreadsheet modeling tool. We used this tool to estimate the economic performance to the property owner of solar PV retrofits at four affordable housing sites located within the City of San Diego, CA. These sites are located throughout the City, and represent a mix of property sizes, layouts, and electricity usage profiles. We considered actual electricity usage data, electric tariff information, and site physical constraints to model PV economics at the four sites.

In addition to this site-specific modeling, we modeled generic PV retrofit costs. We then compared these costs to residential and commercial utility rates in CA IOU territories that would apply in the affordable housing space. We did this to provide a broader sense of how VNM would affect PV project viability across the state.

Before a property owner invests in a PV retrofit, a fundamental question must first be answered:

> *"Does substituting the electricity produced by a PV system for electricity purchased directly from the utility result in lower total costs for both the property owner and tenants over the life of the project?"*

To address this question, the research team developed an economic modeling tool that estimates the bill savings and costs associated with a PV retrofit. The utility bill savings enjoyed by a property owner will come from lower payments for electricity usage in common areas, and any revenue that the property owner may collect by reducing tenants' electricity bills. The costs of PV consist primarily of hardware, installation, maintenance, and financing expenses. If the utility bill savings generated by a PV project over its useful life are greater than the costs of solar, then a project will be economically favorable.

[5] CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Pages 16-17.

Our model estimates the levelized cost of energy (LCOE) to gauge the cost of PV on a 'per unit of energy' basis. The LCOE represents the present value of PV production costs divided by the system's total expected lifetime energy output. We estimated LCOE both with and without the sizable MASH incentive[6] to demonstrate its impact on project economics. For the site-specific modeling, we compared the LCOE to the levelized value of bill savings (LVOS) at each of the sites, which represents the per unit present value of avoided electricity purchases- or bill savings- over the life of the PV system.[7] At a given site, if the value of bill savings (LVOS) is greater than the costs of PV production (LCOE), the PV project will generate a positive net present value (NPV).

How a particular project is financed can have significant implications for project economics. To keep the analysis and interpretation of results manageable in our economic modeling, we simplified the financing structures into four main categories based on the PV system owner's tax status and whether the PV system was financed through debt or paid for with cash. Tax status significantly affects project costs due to the tax benefits associated with PV.

It is critical to understand how the modeling results should be interpreted given the assumptions about tax status and financing structures that we selected. For government or nonprofit property owners, the metrics reported for "tax-exempt" system owners reflect the cost-effectiveness of PV if the government or nonprofit property owner were to own the PV system. From the perspective of a taxable, private sector property owner, the LCOE reported for "taxable" system owners give an indication of PV's cost-effectiveness, assuming that the property owner has the tax appetite to make use of the project's tax benefits. The cost metrics reported for the "taxable" system owner also give an indication of the cost that a PPA or solar lease provider would face, while recognizing that the PPA provider has to cover transaction costs and may have a higher target rate of return than that used in this analysis.

This report is focused on the project economics of property owners installing solar PV on multifamily affordable housing. Noneconomic considerations may also enter into a property owner or policy makers' decision-making when evaluating the costs and benefits of PV. Solar PV projects can provide environmental, educational, job creation, and other benefits that are not considered in our study.

Key Findings

The economic modeling and examination of four San Diego Housing Commission housing complexes we performed provide insight into the cost and value of PV retrofits in the MF affordable housing sector.

Our main findings are the following:

1. Multifamily affordable housing PV retrofits are most cost-effective in properties where there are sizable *common area* loads. Without an incentive such as the MASH rebate, offsetting *tenant load* with PV is economically challenging.

[6] Before a recent CPUC Decision (D 11-07-031) was issued July 20, 2011, the incentive for PV capacity designed to offset tenant load was $4.00/Watt-AC. For PV capacity that offsets common area load, the incentive was $3.30/Watt-AC. The new incentive rates are $2.80/Watt-AC for capacity that offsets tenant load and $2.30/Watt-AC for capacity that offsets common area load.
[7] Credit should be given to LBNL researchers, particularly per a study by Darghouth et. al. (2010) for developing the term the "value of bill savings".

Affordable housing complexes generally have a meter that captures electricity use in shared or 'common' areas. Outdoor lighting, laundry facilities, office space, and mechanical systems such as elevators create common area load. The property owner usually pays the electric bill for this load which may be served on commercial or residential electricity tariffs. Each tenant unit usually has its own meter which is served on a residential tariff. The cost of a PV retrofit must thus be measured against both commercial and residential electricity rates, with consideration given to rate discounts that are available to qualifying low-income tenants.

Electricity rates vary significantly by tariff and customers' particular load profiles. For small commercial customers, rates are currently about \$0.14-\$0.20 per kWh in the three largest CA IOUs (Table ES-3). Rates for larger commercial customers (demand >20 kW and <500 kW) are approximately \$0.11-\$0.18 per kWh, though this can vary significantly depending on a customer's particular electricity load profile.[8] Higher tier residential rates can be as high as \$0.24-\$0.58 per kWh (Table ES-4). Low-income residential tenants in the CA IOU territories, however, pay considerably less for electricity, about \$0.08-\$0.15 per kWh, as they generally consume in the lower tiers of electricity tariffs, are on low-income discounted rates (Table ES-4) and often receive additional California Alternative Rates for Electricity (CARE) discounts.

It is important to keep in mind that current utility rates are not a measure of the *levelized* value of bill savings (LVOS) over the course of the life of a system, because utility rates are not likely to stay constant into the future, because future cash flows should generally be discounted, and because a PV system's performance will degrade over its useful life, which reduces the amount of energy offset. For example, if a property owner is paying \$0.18 per kWh today, then over 25 years, the LVOS is about \$0.24 per kWh, assuming a discount rate of 8 percent, a PV performance degradation rate of 0.5 percent and an annual utility rate escalation of 3 percent per year.

For the sites analyzed in this study that were served on SDG&E's small commercial "A" rate, we estimated the levelized value of bill savings (LVOS) for PV generation dedicated to offsetting common area load at about \$0.22-\$0.24 per kWh over 25 years. We estimated the LVOS for generation dedicated to offsetting tenant load at about \$0.10 per kWh for the sites we analyzed, where tenants were served on SDG&E's low income DR-LI tariff and received CARE discounts.

By our estimates, the levelized cost of energy (LCOE) for a PV retrofit is in the range of \$0.06-\$0.15 per kWh with the MASH incentive and \$0.16-\$0.25 per kWh without the MASH incentive if tax benefits are realized (Tables ES-1 and ES-2). LCOE is significantly higher without the tax benefits, at between \$0.20-\$0.31 per kWh with the MASH incentive and \$0.32-\$0.43 per kWh without the MASH incentive, depending on system size, installed costs, and financing strategy.

Thus, for properties with significant common area load charged at higher end commercial rates, PV retrofits can be competitive with what would be paid for electricity on the common area meter — if tax benefits are utilized — even without the MASH incentive.[9] The lower value of tenants' avoided

[8] Large commercial electricity tariffs in the three major CA IOUs often include both charges for the customer's total kWh usage and the customer's kW demand. The blended per kWh rate paid by customers whose tariffs include demand charges is determined by the customer's specific load profile. The blended rate is defined as the annual bill divided by the annual kWh usage.

[9] The ITC Tax Credit for renewable energy technologies will expire in 2016. The MACRS accelerated depreciation tax benefit has been in place since 1986.

electricity payments makes projects designed primarily to offset tenant load economically challenging without MASH incentives.

2. Virtual Net Metering (VNM) enables property owners to offset tenant load while maintaining the economic viability of a PV project

In an affordable housing context, the higher electricity rates paid for common area consumption generally means that offsetting common area load will provide better economic performance than offsetting tenant load. However, if a property has significant common area load, the margin between the value of the utility bill savings on the common area load and the cost of energy can be high enough to allow the property owner to offset lower-priced tenant load while still maintaining an economically viable project — even without the MASH incentive.

For example, in the case of one of the sites assessed in this study — the Maryland complex — the common area load would be offset by a 13 kW-DC system. At this system size, the levelized value of bill savings (LVOS) is estimated at $0.22 per kWh and the LCOE at $0.17 per kWh (if tax benefits are realized). The building, however, has available roof space for as large as a 33 kW-DC system. With virtual net metering, the property owner can make use of this extra roof space to offset tenant load. The PV system size can be expanded to 23 kW-DC and still break even, even without the MASH incentive.

3. PV retrofits can generate meaningful utility bill savings to tenants, but a portion of those savings would need to be shared with property owners to make systems economically viable without large incentives

PV retrofits can provide meaningful savings on tenant electricity bills. Our estimates of annual bill savings to tenants at one of the four sites examined (Georgia) is $250 per year if all the roof space available for PV is used. With the MASH incentives or other subsidies, property owners may be able to allow much of this savings to flow to tenants and still produce a positive economic return. However, without the MASH incentives — and in some cases, even with the incentives — the property owner would need to share in the tenants' bill savings to make PV retrofits that offset tenant load economically viable.

At two of the sites examined in this study (Georgia and Sycamore), PV retrofits designed to offset a significant portion of tenant load are only viable if a portion of the tenants' bill savings can be used to compensate the property owner for the cost of the PV system. At these sites, this is the case even if PV costs are reduced by the MASH incentive. At the other two sites (Maryland and El Camino), a significant portion of tenant load can be offset without any of the bill savings flowing to the property owner — but only if the MASH incentive is utilized.

If solar PV retrofits that offset tenant load are to be more widely deployed in the MF affordable housing sector without reliance on significant incentives, property owners will need to be able to recoup some PV investment costs by sharing in the tenants' utility bill savings. In our policy recommendations below, we describe possible mechanisms for making this cost recovery possible.

4. The economic performance of PV retrofit projects on affordable housing improves significantly if tax benefits are utilized

As is shown in Tables ES-1 and ES-2, system owners that can utilize PV's tax benefits will experience levelized costs of energy that are considerably lower than entities that are not able to take advantage of those benefits. For example — without the MASH incentive and assuming $7.2 per Watt-AC installation costs— we estimate the LCOE of a 30 kW-AC system at $0.17-$0.21 per kWh for a taxable entity versus $0.34-$0.36 per kWh for a tax-exempt system owner. The utilization of tax benefits can bring project costs more in line with utility bill savings.

This finding is consistent with what CCSE has observed as a program administrator of the MASH Program, where we have seen a proliferation of MASH projects in which third-party financing structures are used such as power purchase agreements and solar leases that enable the utilization of tax benefits. According to a recent MASH program evaluation by Navigant Consulting, over half of MASH program participants are non-profit or government housing developers who cannot utilize the tax benefits associated with PV. According to Navigant, more than three fourths of active MASH projects statewide are being pursued through 3rd party providers.[10] The ability of 3rd party providers to utilize tax benefits and provide other efficiencies to affordable housing property owners means that these providers are likely to play an important role in PV development in the affordable housing sector for years to come.

Policy Recommendations

Based on our findings from this study, we offer three policy/regulatory recommendations that if implemented could expand the solar PV market in the affordable housing sector and beyond:

1. Ensure that MASH program provides appropriate incentives for common area versus tenant loads

As of July 2011, The CA Public Utilities Commission is in the process of evaluating the MASH program and considering what form it will take into the future. Based on our findings in this study, it appears that PV retrofits can be cost-competitive with commercial electricity rates in properties with significant common area usage if tax benefits are utilized. As is outlined above in Finding 1, when tax benefits are realized, we estimate the LCOE of PV retrofits to be in the range of $0.16-$0.25 per kWh without the MASH incentive. This is within striking range of the bill savings that PV would generate on common area meters with significant usage.

Low-income residential tenants, on the other hand, pay considerably less for electricity at about $0.08-$0.15 per kWh in the CA IOU territories. At the properties examined in this study, the levelized value of utility bill savings for tenants was about $0.10 per kWh, well below the cost of a PV retrofit even when tax benefits are realized.

As the MASH Program moves forward, careful consideration should be given to ensure that incentives are not unnecessarily high for projects designed to offset common area load, and are adequate for offsetting tenant load. The level of incentive that will enable property owner to offset tenant load will in part be determined by the degree to which the property owner can recoup the costs of the PV investment

[10] Navigant Consulting. April 2011. California Solar Initiative – Low Income Solar Program Evaluation. Market Assessment Report. Page 90.

by sharing in the utility bill savings enjoyed by the tenants. This issue is explored further in the next policy recommendation 2.

2. Develop a standardized mechanism that would enable property owners to recoup some of the value of electricity bill savings delivered to affordable housing tenants through PV retrofits

Virtual net metering (VNM) enables affordable housing property owners to spread the benefits associated with a PV system among their tenants. It can be challenging, however, for property owners to collect revenue from their tenants in exchange for providing solar generation credits. Without a large cash incentive, like that provided through the MASH program, and in some cases even with the incentive, a property owner would have to derive some cash flow from the reduced electricity costs that the tenants experience in order for a PV retrofit to be economically feasible. Generating this cash flow from tenants will only be viable if transaction costs can be kept low, due to the low electricity bills paid by affordable housing residents and the correspondingly limited amount of revenue that a property owner would get from each tenant.

We propose a mechanism that could enable property owners to recover costs associated with a PV investment in a way that would keep transaction costs relatively low. A standardized method could be developed that would adjust utility allowances in affordable housing complexes to reflect tenants' lower electric bills post PV installation. In the case of publicly-owned housing, the utility allowance adjustment would have to be accompanied by an allowed rent increase to the property owner. In the case of Section 8 properties, the housing assistance payments that property owners receive would have to be adjusted to reflect reduced electricity costs to tenants. *The goal would be to reduce overall housing costs to tenants (rent+utilities), but create some mechanism for property owners to recover PV costs.* Section 7.2 of this report explains this recommendation in further detail.

3. Expand access to virtual net metering beyond the affordable housing sector

According to our modeling, PV retrofits can be cost competitive with more expensive commercial utility rates and higher tier residential rates in California's three major investor-owned utilities when tax benefits are fully utilized, even without cash incentives. Without virtual net metering (VNM) in a multi-tenant setting, the additional costs and complexity of installing a separate system behind each tenant meter can create a barrier to PV investment. Expanding virtual net metering access to market-rate multifamily housing and non-residential tenant-occupied building segments would improve PV project economics in a significant portion of California's building stock.

PV project economics with VNM are likely to be more favorable in market-rate housing as compared to affordable housing, due to the higher electricity prices paid by tenants. In affordable housing, tenant electric bills are generally lower than in market-rate multifamily housing, as tenants tend to use less electricity and are on special discounted tariffs for low-income households. The monetary value of offsetting tenant electricity load through VNM in market-rate housing is thus likely to be greater than in an affordable housing context. Furthermore, property owners have fewer restrictions on adjusting rent in market-rate housing, so it is likely to be easier for property owners to create mechanisms for recovering PV costs from tenants. The same holds true for commercial multitenant buildings, such as shopping malls, office parks, etc.

In July 2011, the California Public Utilities Commission (CPUC) recognized the value of VNM tariffs to other multi-tenant segments of California's building stock and directed CA's three largest IOUs to expand access to virtual net metering tariffs to all residential, commercial, and industrial multi-tenant and multi-meter properties.[11]

Table ES-1. PV LCOE by system owner and financing type *without MASH incentive*

		Levelized Cost of Energy (LCOE) $/kWh			
		Taxable System Owner		Tax-Exempt System Owner	
System Size kW-AC	$/Watt-AC	100% Cash	Debt Financed	100% Cash	Debt Financed
5	$8.7	0.246	0.201	0.411	0.428
30	$7.2	0.208	0.171	0.348	0.356
300	$6.6	0.192	0.158	0.322	0.333

Notes: Assumes ITC Credit and MACRS tax benefits are realized for taxable system owner. AC Capacity Factor of 21%. Cost estimate by system size based on 2009 and 2010 data from California Solar Statistics.

Table ES-2. PV LCOE by system owner and financing type *with MASH incentive*

		Levelized Cost of Energy (LCOE) $/kWh			
		Taxable System Owner		Tax-Exempt System Owner	
System Size kW-AC	$/Watt-AC	100% Cash	Debt Financed	100% Cash	Debt Financed
5	$8.7	0.150	0.105	0.290	0.307
30	$7.2	0.112	0.074	0.226	0.234
300	$6.6	0.096	0.063	0.201	0.211

Notes: Assumes MASH incentive at 3.30 per Watt-AC. ITC Credit and MACRS tax benefits are realized for taxable system owner. AC Capacity Factor of 21%. Cost estimate by system size based on 2009 and 2010 data from California Solar Statistics.

[11] CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Pages 16-17.

Table ES-3. Commercial tariffs across California's three largest IOUs

IOU		Commercial Tariff Structures*			
		Flat Rates w/ Seasonal Variation	Flat Rates w/Seasonal Variation and Demand Charges	Time of Use Rates w/Seasonal Variation	Time of Use Rates w/Seasonal Variation and Demand Charges
SDG&E	*Tariff Name*	A	No open tariff	No open tariff	AL-TOU
	Requirements	Demand ≤ 20kW	N/A	N/A	Demand > 20 kW
	Rates	$0.15/kWh-$0.19/kWh	N/A	N/A	Energy Charges** ($0.08/kWh-$0.11/kWh) Demand Charges** ($5.00/kW-$13.00/kW)
SCE	*Tariff Name*	GS-1	GS-2	TOU GS-1	GS-2-A or TOU-GS-3-A,B, or CPP
	Requirements	Demand ≤ 20kW	Demand >20 and ≤ 200kW	Demand ≤ 20kW	Demand >20 and ≤ 200kW for GS-2 Demand >200 and ≤ 500kW for GS-3
	Rates	$0.14/kWh-$0.19/kWh	Energy Charges** $0.08/kWh-$0.09/kWh Demand Charges ** $12.00/kW-$19.00/kW	$0.11/kWh-$0.38/kWh	Energy Charges** GS-2-A/B $0.07/kWh -$0.34/kWh TOU-GS-3 A/B/CPP $0.06/kWh -$0.26/kWh) Demand Charges** $0.00/kW-16.00/kW
PG&E	*Tariff Name*	A-1-A	A-10-Non-TOU	A-1-B & A-6	A-10
	Requirements	Demand <200 kW	Demand <200kW	Demand <200kW for A-1 Demand ≤499kW for A-6	Demand ≤499 kW
	Rates	$0.14/kWh-$0.20/kWh	Energy Charges ** $0.11/kWh-$0.14/kWh Demand Charges** $6.00/kW-$11.00/kW	A-1-B $0.14/kWh - $0.22/kWh A-6 $0.12/kWh - $0.45/kWh	Energy Charges** $0.10/kWh -0.16/kWh Demand Charges** $6.00/kW-$11.00/kW

*Probable common area meter usage limited to less than 500 kW per month.

**The blended per kWh rate paid by customers whose tariffs include demand charges is determined by the customer's total kWh usage and the customer's kW demand. The blended rate is defined as the annual bill divided by the annual kWh usage. Different customers have different load profiles -energy usage and demand- and so will pay different blended rates per kWh. Based on our modeling of tariff structures for clients in the three major CA IOUs, we find that demand charges generally add about $0.05-$0.10 per kWh to the energy charges applicable on a given tariff. Wiser et. al. (2007) found that demand charges add approximately $0.03/kWh-$0.10 per kWh to energy charges in a study of commercial utility customers in California. See: Wiser, R., Mills, A., Barbose, G. and Golove, W. (2007) The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California. *LBNL-63019* p. 25

Table ES 4. Residential tariffs across California's three largest IOUs

IOU		Residential Tariff Structures (Rates are in $/kWh)			
		Volumetric Tiered w/ Seasonal Variation	Volumetric Tiered w/Seasonal Variation and Low Income Discount	Seasonal Variation, No Tiers	Tiered Time of Use Rates w/Seasonal Variation
SDG&E	*Tariff Name*	DR	DR-LI	No Open Tariff	DR-TOU
	Requirements	Domestic Residential	Qualifying Low-Income Domestic Residential	N/A	Domestic Residential
	Rates	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 –$0.27-$0.28 Tier 4 –$0.29-$0.30	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 – $0.21-$0.22 Tier 4 – $0.21-$0.22	N/A	Tier 1 – $0.14 Tier 2 – $0.14 Tier 3 – $0.24-$0.28 Tier 4 – $0.28-$0.40
SCE*	*Tariff Name*	D	D-CARE	TOU-D-1&2	TOU-D-T
	Requirements	Domestic Residential	Qualifying Low-Income Domestic Residential	Domestic Residential	Domestic Residential
	Rates	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 – $0.24 Tier 4 – $0.28 Tier 5 – $0.31	Tier 1 – $0.09 Tier 2 – $0.11 Tier 3 – $0.18 Tier 4 – $0.18 Tier 5 – $0.18	TOU-D-1 – $0.17-$0.42 TOU-D-2 – $0.15-$0.34	Tier 1 - $0.12-$0.20 Tier 2 - $0.22-$0.54
PG&E	*Tariff Name*	E-1	EL-1	No Open Tariff	E-6
	Requirements	Domestic Residential	Qualifying Low-Income Domestic Residential	N/A	Domestic Residential
	Rates	Tier 1 – $0.12 Tier 2 – $0.14 Tier 3 – $0.29 Tier 4 – $0.40 Tier 5 – $0.40	Tier 1 – $0.08 Tier 2 – $0.10	N/A	Tier 1 – $0.09-0.30 Tier 2 – $0.11-0.32 Tier 3 – $0.26-0.47 Tier 4 – $0.37-0.58 Tier 5 – $0.37-0.58

* SCE generation charges are calculated using a percentage of energy supply from DWR sources, which change daily.

1. Introduction

The following report provides an analysis of solar photovoltaic (PV) retrofits in the multifamily affordable housing sector, with a particular focus on the impact of virtual net metering (VNM) and MASH incentives on project economics. This study was produced by the California Center for Sustainable Energy (CCSE) in partnership with the City of San Diego's Environmental Services Department, through funding from the Department of Energy's (DOE) Solar America Cities (SAC) Program. CCSE performed this analysis to help property owners, tenants, and other stakeholders better understand PV retrofit economics in the multifamily affordable housing sector and to inform policy makers about the impacts of incentives and virtual net metering tariffs on project viability.

In this study, we investigated the economic value proposition of PV retrofits in a MF affordable housing setting using a custom-built modeling tool. We used this spreadsheet-based tool to estimate the economic performance of solar PV retrofits at four affordable housing sites located within the City of San Diego based on actual electricity usage data, electric tariff information, and site physical constraints. These sites are located throughout the City of San Diego, CA, and represent a mix of property sizes, layouts, and electricity usage profiles.

In addition to this site-specific modeling, we modeled generic PV retrofit costs. We then compared these costs to residential and commercial utility rates in CA IOU territories that would apply in the affordable housing space. We did this to provide a broader sense of how VNM would affect PV project viability across the state.

Section 1 provides information about California's Multifamily Affordable Solar Housing (MASH) program, describes virtual net metering (VNM) tariffs, and outlines the study objectives. Section 2 details the economic modeling performed, explains the key assumptions that were used, and outlines how the modeling results can be interpreted. The four study sites are described in Section 3. In Section 4, we present the results of our economic modeling of PV retrofits at the study sites. In Section 5, we present the results of our generic cost modeling of PV retrofits and compare PV costs to the cost of electricity purchased from CA IOUs. Research findings are summarized in Section 6. In Section 7, we offer policy recommendations based on our findings.

1.1. The MASH Program

In early 2009, the CPUC launched the California Solar Initiative (CSI) MASH Program across the state's three major investor owned utilities (IOUs), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). The $108.34 million program was established with the following goals:

- Stimulate the adoption of solar power in the affordable housing sector
- Improve energy utilization and overall quality of affordable housing through the application of solar and energy efficiency technologies
- Decrease electricity use and costs without increasing monthly household expenses for affordable housing building occupants
- Increase awareness and appreciation of the benefits of solar among affordable housing occupants and developers

Similar to the CSI General Market Program, MASH pursues these goals with rate-payer funded rebates for solar photovoltaic (PV) retrofits. In the MASH Program, the $3.30-$4.00/Watt-AC[12] rebates are available up front and can offset a significant portion of project costs, which generally run in the $6.00-$9.00/Watt-AC range for total installed costs. As program administrator of the MASH Program in the SDG&E service territory, CCSE offers specific insights in this report that originate from our active role in implementing the program and guiding its participants.

Policy makers and market stakeholders expected that the combined benefit of state and federal incentives would lead to rapid large-scale adoption of solar by multifamily (MF) affordable housing owners. However, reservations were slow immediately following program launch due to a lack of market awareness about project economics and the value of solar retrofits in an affordable multifamily housing setting. Specifically, multifamily property owners and operators lacked understanding of how to determine the impact a PV system would have on utility costs of both tenants and property owners and how project costs could be recouped. Some complexity was also created by the introduction of a new tariff structure designed specifically for the MASH Program. The virtual net metering (VNM) tariff improved the economic viability of PV projects in the MF sector, but also introduced some near-term uncertainty into the project development process.

1.2. Solar PV and Affordable Housing

Promoting PV retrofits in multifamily affordable housing brings challenges specific to this sector. Foremost among these is the building owners' conservative economic approach to project development. This approach stems from the complex financing structures and limited profit margins typically experienced by property owners in the sector, which make novel capital-intensive projects such as on-site PV systems a difficult sell.

Property owners can also be wary of such investments when there are few model projects to emulate. Distributed PV projects have a history of demonstrated value in the commercial and residential market sectors. However, the utility metering structure and cost recovery mechanisms applicable to multifamily affordable housing developments makes experience from other sectors only partially transferable.

1.3. Virtual Net Metering

As a companion to MASH incentives, the CPUC required the CA IOUs to develop a new utility tariff called virtual net metering (VNM). This innovative solution addressed key barriers to PV deployment in a multitenant setting. Virtual net metering allows property owners to distribute solar net energy metering (NEM)[13] generation credits to multiple tenants from a single solar PV system.

In most tenant-occupied buildings, each tenant has a separate meter, rather than the building having a single master meter. Separate metering means that each tenant pays for the precise amount of electricity used and encourages each tenant to use energy efficiently. Separate tenant metering is thus beneficial

[12] Before a recent CPUC Decision (D 11-07-031) was issued July 20, 2011, the incentive for PV capacity designed to offset tenant load was $4.00/Watt-AC. For PV capacity that offsets common area load, the incentive was $3.30/Watt-AC. The new incentive rates are $2.80/Watt-AC for capacity that offsets tenant load and $2.30/Watt-AC for capacity that offsets common area load.

[13] Net energy metering (NEM) allows utility customers with PV systems to draw energy from the grid when their solar system is producing less electricity than what is needed on site and to obtain credits for electricity fed into the grid when the solar system is producing more electricity than what is needed on site.

from an energy efficiency perspective. Under current NEM rules, however, a separate PV system would have to be installed behind each tenant meter for the tenants to enjoy the benefits of NEM (Figure 1). Virtual net metering tariffs allow a property owner to install one solar PV system and share the credits *virtually* among tenants (Figure 2). That is, the solar NEM credits are determined for the single PV system, and then those credits are distributed mathematically to each tenant's bill at a predetermined allocation.

VNM tariffs address two major barriers to installing solar PV systems in a multitenant context:

1. *The added cost and complexity of installing a single PV system behind each individual tenant utility meter*

   The VNM tariff allows project developers to install one PV system per service delivery point (SDP)[14], whose kilowatt-hour energy can then be shared with all meters (tenant and common area) on a property that resides behind the SDP. This reduces costs and improves the value proposition of PV installations. It is important to note, however, that in the CA IOU service territories, the VNM tariff does not currently allow for customers behind different SDPs to share a generation resource.[15]

2. *The fact that tenants cannot afford the capital expense of solar and are unlikely to stay in a unit for the estimated 25 year life of a PV system*

   In almost all tenant-occupied building scenarios, tenants are unlikely to stay in a particular unit or building long enough to make it worthwhile to invest in an individual PV system. Even longer term commercial leases generally involve commitments of no more than about ten years, while solar PV systems can have life spans of more than 25 years. In an affordable housing complex, as in any residential rental situation, tenants have little assurance that they will stay in a unit for a long enough period to make investing in solar viable. VNM enables the property manager to invest in solar on behalf of what will likely be many different tenants over the life span of the PV system.

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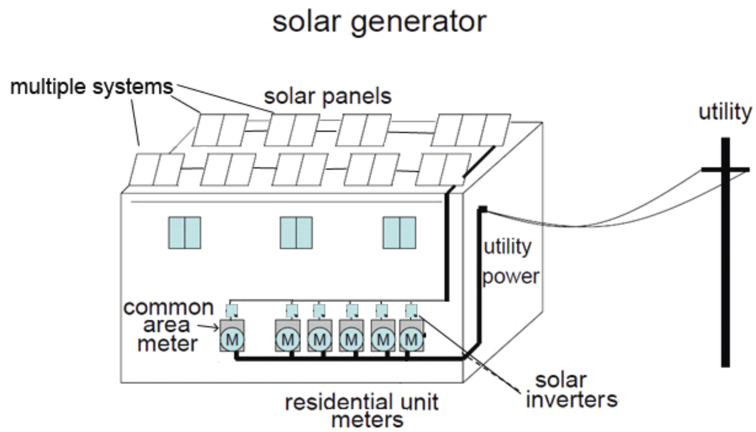
[14] The service delivery point is where the utility's service facilities are connected to either the applicant's (i.e. customer's) conductors or other service termination facility designated and approved by the utility. www.sdge.com/tm2/pdf/ELEC_ELEC-RULES_ERULE16.pdf.

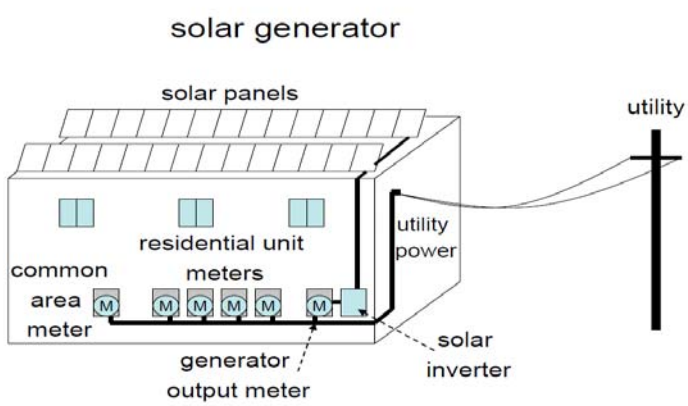
[15] The California Public Utilities Commission (CPUC) has directed the IOUS to allow (in affordable housing complexes only) property owners to share VNM credits between buildings that are behind different service delivery points. See CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Pages 12-13.

Figure 1. Multitenant building and PV under current net metering rules



Source: California Public Utilities Commission www.cpuc.ca.gov.

Figure 2. Multitenant building and PV under virtual net metering

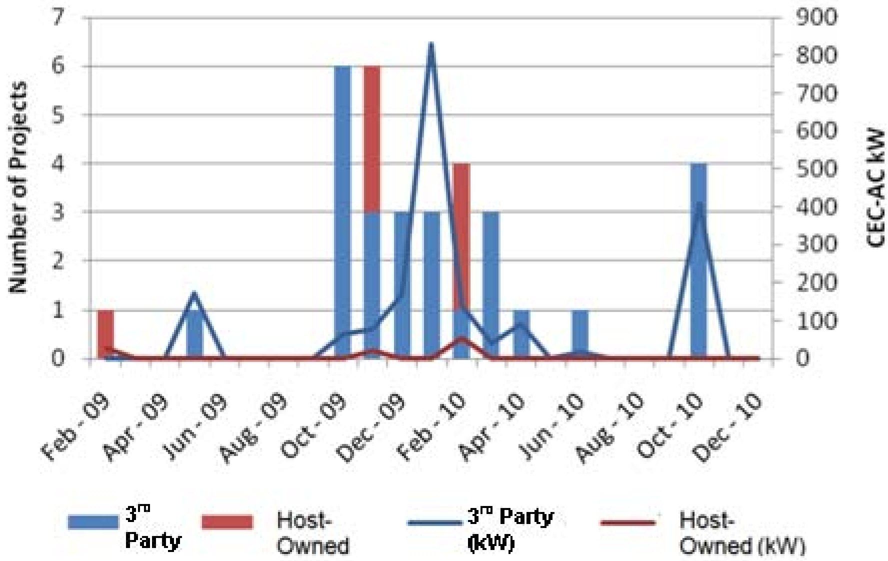


Source: California Public Utilities Commission www.cpuc.ca.gov.

1.4. Current Status of the MASH Program

In the months following the MASH Program launch, incentive reservations moved slowly. This changed, however, when solar power providers began leveraging substantial MASH incentives and tax benefits to offer very competitive 3rd party ownership arrangements in the form of power purchase agreements (PPAs) or solar leases (Figure 3). These ultimately proved to be an attractive project development mechanism for affordable housing property owners due to the little or no up-front costs and PPA or lease rates that were considerably lower than utility electricity rates. A smaller number of affordable housing owners also began work on host-customer owned PV systems. In these cases, capital costs have been funded primarily through government grants.

Figure 3. Application volume of MASH Projects in the SDG&E service territory.



Demand for MASH incentives eventually outgrew available funding. The MASH program was divided into two "tracks". Track 1 incentives are available to all projects that meet program requirements while Track 2 projects were subject to a competitive selection process. Since June 2010, Track 1 projects have been fully subscribed and a number of Track 2 projects have been awarded. A decision issued on July 20, 2011 by the CPUC ordered the program administrators to use remaining Track 2 funds to incentivize projects currently on the wait list for Track 1.[16] If all projects currently on the program administrators' waitlists were to be completed, the majority of remaining Track 2 funds would be exhausted. Thus, at current funding and subscription levels, there will be limited opportunity for affordable housing property owners to access MASH incentives into the future.

As of February 2011, over thirty San Diego area MASH projects were in various stages of the development process, with seven projects installed. In all three major CA IOUs, 36 projects have been installed representing a capacity of about 2 MW. About 330 MASH projects are in various stages of the development process statewide, representing a capacity of 16 MW.[17] An additional 4.4 MW worth of projects are on the IOUs' waiting lists for a MASH incentive, about 56 projects.

What is uncertain at this stage in the program is whether the MASH incentives and the new virtual net metering tariff will spur a transformation in the affordable housing sector, such that PV retrofits will be more widely adopted after the incentive program sunsets.

1.5. Study Objectives

This research seeks to characterize the economic performance of PV retrofits in the multifamily affordable housing sector. Further, we seek to understand to what extent the VNM tariff can be used to cost-effectively offset tenant load. To do this, we performed an economic analysis of PV retrofits at four

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[16] CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Page 51.

[17] Semi-Annual MASH Program Report to the CPUC by PG&E, SCE, and CCSE. February 2011.

affordable housing complexes owned by the San Diego Housing Commission. These sites are located throughout the City of San Diego, CA, and represent a mix of property sizes, layouts, available installation areas, common area loads, and tenant loads. The economic viability of each site was modeled using a custom-built pro forma cash flow analysis tool that examines the impact of various system ownership types, financing structures, system sizes, utility rates, and allocations of solar credits to tenants.

The model was also used to provide generic estimates of the levelized cost of energy (LCOE) of PV retrofits under various system sizes and ownership/financing structures. These costs were then compared to residential and commercial utility rates in CA IOU territories that would apply in the affordable housing space to get a broader sense of how VNM would affect PV project viability across the state.

1.6. Existing Literature and Resources

In this section, we review existing literature and resources that informed the approach and methods we used to model PV project economics for this report. A number of studies have examined the project economics of distributed solar PV. Some have focused on the bill savings that solar PV generates, some have looked at the cost of distributed PV, and some have examined both.

Darghouth et. al. (2010) used actual customer load data to estimate the bill savings that would accrue to residential PV customers of CA's two largest investor owner utilities (IOUs) under current and proposed net metering rules. Among other findings, Darghouth found that the per kWh bill savings generated by residential PV systems vary significantly due to tiered electricity rates, varying from as low as $0.12 to about $0.35 for the customers included in the study. In 2008 and 2007 studies, Mills et. al. and Wiser et. al. examined the value of bill savings generated by PV in the commercial sector across major utilities in CA. These studies found that the value of bill savings varied considerably depending on the customer's load profile, the size of the PV system, and the particular tariff the customer is on. Among the three largest IOUs in CA, the first year per kWh bill savings associated with a PV system for commercial customers varied from about $0.10 to $0.20 per kWh.[18]

These studies illustrate how the value proposition of distributed PV under net metering depends heavily on the particular load profile of a given customer and the tariff that determines a customer's electric rates. In our study, we were able to collect actual electricity usage data and tariff information at the four sites we examined. This allowed us to model with relative accuracy the bill savings produced by different sized PV systems at the study sites, under varying allocations of solar credits between tenant and common areas meters that are allowed under a VNM tariff.

Relatively few published studies have estimated the cost of distributed solar on a *dollars per kWh* basis that can be compared to bill savings and electricity rates in CA. The Lawrence Berkeley National Laboratory has produced a series of reports entitled "Tracking the Sun" which have tracked the installed costs of distributed PV on a *dollars per kW* basis in CA and around the US. The latest of these studies shows a decline in installed PV costs since 1998 of about 3 percent per year. Bolinger (2009) modeled the per kWh cost of distributed solar PV for non-residential customers under various financing structures. His study provides valuable insight into the impact of financing structures on project economics. Borenstein (2008) examined the cost of distributed solar in comparison to time-dependent values of wholesale energy prices. More recently (2010), Energy, Environment, and Economics (E3) produced a

[18] Wiser et. al 2007 page 21 for 75% PV penetration in the three IOUs.

spreadsheet-based tool that models the project economics of distributed PV to inform a cost-effectiveness evaluation of the CA Solar Initiative that was completed in April 2011. This tool, the aforementioned studies, and the National Renewable Energy Laboratory's Solar Advisor Model (SAM) provided valuable guidance for modeling the cost of distributed PV in our study.

2. Economic Modeling

To gauge the viability of PV retrofits at each of the four study sites, we collected site physical characteristics and electricity consumption history, modeled PV system production and how that production would impact electricity bills, and estimated economic performance. This section outlines model design, reviews applicable utility tariffs, and describes key model assumptions.

The economic modeling we performed is comparable to a first-cut analysis that a PV developer or property owner might conduct to get a general sense of whether a project is viable. Cost, financing, and ownership parameters specific to a particular project will have significant implications for economic performance. Our modeling results should thus be interpreted as benchmarks. Project-specific financial modeling should be performed to assess the performance of any particular project.

2.1. Cash Flow Modeling

When a property owner invests in a distributed energy resource like PV, a fundamental question must first be answered:

> *"Does substituting the electricity produced by a PV system for electricity purchased directly from the utility result in lower total costs for both the property owner and tenants over the life of the project?"*

To address this question for the study sites, the research team developed a spreadsheet-based modeling tool that accounts for all major cash inflows and outflows associated with a PV retrofit, including those unique to multifamily affordable housing developments.

Major cash inflows accounted for in the model include:

- Avoided Utility Payments- Bill Savings (Common Area Load and/or Tenant Load)
- Cost Recovery from Solar Credit Allocation to Tenants (Utility Allowance Adjustment)
- Applicable Cash Incentives (MASH Incentives at $3.30-$4.00/Watt)
- Federal Investment Tax Credit (ITC) or 1603 Cash Grant[19]
- Modified Accelerated Cost Recovery Schedule (MACRS) Benefits[20]

[19] Under current legislation, the 30 percent ITC for solar PV will terminate at the end of 2016. The cash grant in lieu of the tax credit authorized by the American Recovery and Reinvestment Act of 2009 Section 1603 expires at the end of 2011. Projects must be under construction by the end of 2011, but can come online as late as 2016. The ARRA 1603 'grant in lieu of tax credit' measure was implemented to address a significant decrease in demand from tax equity investors.

[20] The MACRS depreciation schedule allows owners of selected energy technologies to depreciate those technologies on an accelerated 5-year schedule. In December 2010, the bonus depreciation was modified by the *Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010 (H.R. 4853)*. Under the new rules, eligible property placed in service before January 1, 2012, qualifies for 100% first-year bonus depreciation. For 2012, bonus depreciation is still available, but the allowable deduction reverts from 100% to 50% of the eligible basis. For these years, the value of the tax benefits will be higher that what was modeled in this study.

Major cash outflows accounted for in the model include:

- Up-front Capital Cost of the System
- Operation and Maintenance (O&M) Costs
- Financing Costs (if debt financed)
- Other Transaction Costs (such as debt issuance costs)

2.1.1. Accounting for Virtual Net Metering

Our economic model accounts for the ability of a property owner to distribute solar net energy metering (NEM) credits to tenants through a virtual net metering (VNM) tariff. Affordable housing complexes, like other multitenant complexes, will generally have a single common area meter for which the property owner pays the electric bill. As described in Section 1.3, each tenant unit generally has its own meter, and tenants will usually pay for their own electric bills. The model includes variables that allow the user to choose typical residential tariff structures, enter average tenant load profiles, and select different levels at which to allocate solar generation credits between common area meters and among tenants.

2.1.2. Utility Allowances, Rent, and Recovering Costs from Tenants

In order for PV to represent a viable investment for property owners, they must be able to recover an appropriate level of investment costs. Virtual net metering enables property owners to spread the benefits of energy produced by a single grid-connected PV system among their tenants. It does not, however, directly provide a vehicle for property owners to collect revenue from their tenants in exchange for allocating solar generation credits to them.

For affordable housing units, by Federal Housing and Urban Development (HUD) regulations, tenant rents are capped at 30 percent of a household's annual income.[21] This "gross rent" includes both the payment for the unit rental and any cost associated with living at the complex that is not paid by the property owner, such as utility costs. A utility allowance (UA) is applied to a given unit that is designed to compensate the tenant for utility costs (primary electricity, gas and water), such that the gross rent does not exceed 30 percent of the tenant's income.

In the context of affordable housing, one means for deriving cash flow from the reduced utility costs the PV provides to tenants is to adjust utility allowances. Utility allowances could be reduced to reflect the lower electric bills experienced by tenants in a complex that has a solar PV system (See Section 7.1 for further discussion). The idea would be to lower the tenant's gross rent, but allow more rent to be paid to the property owner in exchange for reduced tenant electric bills. To account for this option, we include a variable that determines how much revenue the property owner is able to derive from the avoided utility costs enjoyed by the tenants. We assume that regulatory guidance would require the property owner to leave a significant portion of the tenant electricity bill savings with the tenant, and that the owner would receive only a portion (75%) of the value of the offset energy.[22]

[21] See HUD Fact Sheet at http://www.hud.gov/offices/pih/programs/hcv/about/fact_sheet.cfm.

[22] According to Department of Housing and Urban Development, "Field Office Review Procedure: Energy Performance Contracting"(2005) pp. 6-8, a public housing authority may retain as much as 75% of the stream of cash savings generated by energy efficiency improvements to pay for the improvements, including servicing the debt. Also, assuming that the property owner can retain 75% of the value of avoided purchases is in line with modeling done by Global Green for the CA Energy Commission, See Global Green's Solar Affordable Housing Calculator at: http://www.globalgreen.org/solarcalculator/.

2.2. Utility Tariff Structure

When an affordable housing property owner is considering the economics of a PV system, a key consideration is how the cost of self generation compares with the cost of purchasing the same electricity from the utility. This section reviews the tariffs used to provide service at the four study sites and compares their structure and rates. For the site-specific modeling, we predicted the impact that a solar PV retrofit would have on tenant and common area electricity bills using the particular tariff structures applicable to a given site.

California utility rates vary by customer class, level of service, annual consumption, and peak demand. The applicable utility rates for the sites included in this research, however, are somewhat less complex due to the relatively small size of tenant energy consumption and low electricity demand of these modestly sized properties. At these properties, there are two primary divisions of service to consider: 1) tenant meters on residential rates, and 2) common area meters on small commercial or residential rates. Tenant meters serve all usage in the resident occupied units, while common area meters serve building load not associated with individual tenant use. Common area meters generally account for electricity used for outdoor lighting, laundry facilities, office space, and mechanical systems such as elevators.

2.2.1. Tenant Load and Residential Rates

Most domestic residential usage in California is charged on a volumetric tiered structure through which users pay different prices per unit of electricity based on the total volume of energy consumed in a given billing period. For the four affordable housing projects analyzed here, all tenant loads are billed under this structure. The SDG&E domestic rate (DR) and low-income domestic rate (DRLI) both have four tiers, with a progressive pricing structure in which increased consumption results in higher per unit costs.

The size of individual tiers is based on the customer's baseline, which is determined by their Climate Zone (Figure 4) and primary heating fuel. These two factors allow the baseline and tiered structure to account for variation in the basic electricity needs of various customers (Table 1).[23] All baseline usage is charged at the Tier 1 rate, 101-130 percent of baseline is charged at Tier 2, 131-200 percent of baseline at Tier 3, and all remaining consumption is charged at the Tier 4 rate.

[23] For example, a customer living in the mountain climate zone with electric heat will have larger tiers and a higher volume of inexpensive electricity than a customer living in the coastal climate zone with gas heat.

Figure 4. Climate zones in the SDG&E service territory

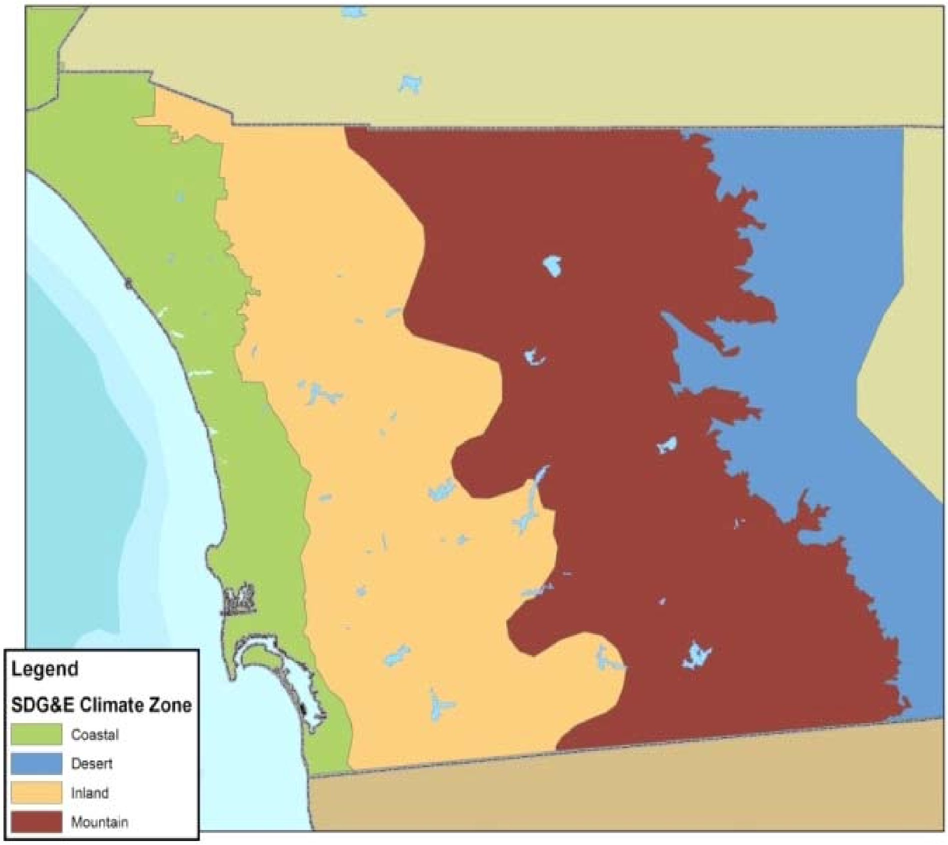

Table 1. Daily baseline energy allowance (kWh) based on climate zone and heating type

Homes without Electric Heat

	Coastal	Desert	Inland	Mountain
Summer	9.6	16.4	11.2	14.8
Winter	10.4	11.2	10.8	13.8

Homes with Electric Heat

	Coastal	Desert	Inland	Mountain
Summer	9.8	19.5	11.0	17.3
Winter	16.6	22.0	18.3	28.5

All of the residential accounts analyzed in this research are provided service on the SDG&E DRLI tariff. This discounted rate is available to residential customers for all regular domestic energy uses, provided they meet total gross annual income requirements. Rates charged under this schedule are similar in Tiers 1 and 2, but the prices are discounted approximately 22 percent for Tier 3 consumption and 27 percent for

Tier 4 (Table 2). Most of the tenants in this study also take advantage of the CARE allowance that reduces monthly electricity charges by 20 percent.

Table 2. SDG&E DR and DRLI Residential Tariffs

	DR		DR-LI	
	Summer	Winter	Summer	Winter
Tier 1	$0.1341	$0.1341	$0.1274	$0.1274
Tier 2	$0.1549	$0.1549	$0.1482	$0.1482
Tier 3	$0.2820	$0.2655	$0.2224	$0.2081
Tier 4	$0.3020	$0.2855	$0.2224	$0.2081

2.2.2. Common Area Load and Tariff Options

Common area meters at facilities such as multifamily housing complexes are unique in that they qualify to take service under either a residential tariff or a commercial tariff. At the complexes we evaluated, the applicable commercial tariff was the SDG&E "A" small commercial tariff. When accounts are provided service under a domestic ("D") rate, the tariff structure and pricing match what is outlined above in Table 2. When the account is provided service under the "A" rate, however, it is charged a seasonally adjusted flat rate of between $0.15-0.19 per kWh for all electricity provided.

2.2.3. Service Delivery Points

At the four study sites examined, each site had only one service delivery point (SDP). This means that solar credits produced by a solar PV system at a given site can be allocated through virtual net metering to common area and tenant meters without restriction. As is explained in Section 1.3, current tariffs allow for virtual net metering only behind a given SDP. It is important to keep in mind that a given property may have more than one SDP, especially at larger complexes with multiple buildings. This may limit the ability of the property owner to distribute solar credits through virtual net metering from a single PV system. If a property has multiple service delivery points, the property owner may have to install separate systems for each SDP and may be unable to distribute solar credits in the most economically efficient or equitable manner among different common area and tenant meters. This could significantly decrease the cost-effectiveness of PV.

2.3. Measures of Economic Performance

We used several metrics to evaluate the economic performance to the system owner of PV retrofit projects on multifamily affordable housing. These include:

- Year 1 Electricity Bill Savings to Tenants and Property Owners
- Levelized Cost of Energy (LCOE)
- Levelized Value of Bill Savings (LVOS)
- Net Present Value (NPV)

Each metric has its particular uses (Table 3), and taken together, they give a more complete sense of a PV project's economic performance. These metrics are explained below and are described in more detail in Appendix A - Measures of Economic Performance.

2.3.1. Year 1 bill Savings

A critical measure of project viability is utility bill savings. From the tenants' perspective, their already limited incomes mean that electric bill savings can free up money for other important needs. From the property owner's perspective, electricity bill savings must be weighed against the capital costs of the PV system if the property owner owns the system, or the cost of a power purchase agreement or lease payment if a 3rd party owns the system. First-year bill savings can be calculated with a high degree of accuracy. However, future utility rates are likely to change, and most likely escalate (at least on a nominal basis), so bill savings in the future may be higher.

2.3.2. Levelized Cost of Energy (LCOE)

We used the levelized cost of energy (LCOE) to evaluate the cost of producing PV electricity on a per unit of energy basis. The LCOE is the present value of the costs of energy production, including O&M costs, divided by the total energy produced during the product's useful life. This gives a price per unit of energy, generally represented in dollars or cents per kWh.

Because tax impacts significantly affect the cost of renewable energy, we estimated the **after-tax LCOE** in our modeling. As is further detailed in Section 2.4, the tax impacts of owning PV vary considerably by sector. We defined the LCOE in a manner that reflects the costs experienced by the system owner, accounting for any cash incentives and tax benefits.

The LCOE is a useful metric for evaluating the cost of producing energy across various technologies, sizes, time scales, and financing structures. The LCOE can be compared to per kWh costs of alternative technologies and to grid-supplied electricity to evaluate the cost-effectiveness of distributed energy resource projects.

2.3.3. Levelized Value of Bill Savings (LVOS)

When modeling cash flows for a distributed energy resource (DER) like solar PV that is displacing grid-supplied energy, the major source of cash inflow to the host customer is the savings generated by the DER. That is, the purchases of energy from the utility that the DER host customer no longer has to make thanks to the on-site energy produced.

Over the life of the PV system, the total bill savings can be levelized to give a sense of what the host customer would have had to pay had he not invested in a PV system. We have termed this the "levelized value of bill savings" (LVOS), the present value of the bill savings on a per kWh basis.[24] This metric is dependent on the particular utility service territory in which the customer is located and the tariff schedule applicable to the customer. Tariff schedules usually vary by the customer's sector — commercial, industrial — as well as the level of the customers' peak energy demand (measure in kW).

The LVOS can then be compared to the LCOE of the PV system. If the LVOS is greater than the LCOE, then the project will result in electricity cost savings compared to purchasing grid-supplied energy. The

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[24] For the concept and term, the "Levelized Value of Bill Savings" we drew on work done by LBNL researchers, particularly Darghouth et. al. (2010) who utilized the term and concept of the "value of bill savings", Bolinger (2009) who formulated the concept of a "levelized revenue requirement", and Mills (2008) and Wiser (2007) for their conceptualization of the "value of PV" on a $/kWh basis.

LVOS can also be used as a benchmark to compare to the energy price offered through a power purchase agreement (PPA).

For taxable host customers who choose to own their own systems, it is important to consider the tax impacts of losing the tax deduction that can be claimed for electricity bills. When a property owner invests in a solar system, they are capitalizing an operating expense. A taxable owner gains the ability to deduct capital depreciation expenses from taxable income but loses the ability to deduct utility expenses from taxable income. This can have a significant negative impact on a system owner's cash flow.

For example, if a system owner is saving $3,000 a year in electricity bills thanks to the production provided by a solar PV system, they may see their taxes increase by $3,000 times their effective tax rate. We chose not to include this impact in the LCOE or "cost side" of the equation because the impact of the loss of the utility costs tax deduction will vary considerably by the particular tariff that a customer is on. This impact should be considered, however, when looking at the "benefits side" of the equation – the LVOS – or what is the value of the bill savings provided by a PV system.

2.3.4. Net Present Value

The LCOE and LVOS provide a sense of the costs and benefits of a project per kWh of consumption and production. These metrics do not, however, provide a measure of the overall value of a PV investment. The net present value (NPV) is a commonly used metric to evaluate investment value. To establish the NPV of an investment, all cash inflows and outflows are estimated over the life of the investment and all net cash flows are discounted to present value. The sum of all discounted net cash flows is the NPV of the investment.

If NPV is greater than zero, the investment will be profitable. The NPV as an overall dollar amount also gives a sense of the scale of profitability. It is important to understand that this metric is sensitive to the discount rate used to discount cash flows to present value. The discount rate is the rate of return that an investor would expect to achieve were he to invest in an alternative investment of comparable risk to a solar PV project.

Table 3. Summary of economic performance metrics

Metric	Definition	Interpretation	Considerations
Yr. 1 Bill Savings	Avoided electricity purchases by the property owner and tenants due to PV production	Gives a sense of cash flow to the property owner and tenants	Does not account for future electricity rate changes
LCOE	Levelized Cost of Energy ($/kWh) - Present value of all costs over the project life span divided by the present value of PV production in kWh	Provides common unit of comparison of energy costs across various technologies and project scales. Can also be compared to utility rates	Sensitive to choice of discount rate and assumptions about PV production
LVOS	Levelized Value of Bill Savings ($/kWh) - The value of bill savings attributable to the on-site PV generation divided by the present value of PV production in kWh	Varies by tariff and can be calculated for a specific customer. Can be compared to LCOE and the per unit energy cost of a PPA.	Sensitive to choice of discount rate and assumptions about PV production and future electricity rate changes
NPV	Net Present Value ($) - Present value of all cash inflows and outflows over the life of the project	Accounts for the scale of the investment. Provides single measure of costs and benefits	Sensitive to choice of discount rate and assumptions about PV production and future electricity rate changes

2.4. Impact of Financing Structures on Project Economics

The financing strategy that a PV system owner employs can dramatically affect the economics of a project.[25] Access to funding and financing for solar PV retrofits on a given affordable housing property will vary based on a number of factors. In this section, we review what types of financing are likely to be available for solar in an affordable housing context. We then outline the financial parameters we chose for the economic modeling in this study.

2.4.1. Funding/Financing Sources for PV in Affordable Housing

Funding and financing opportunities are different for investments in publicly-owned versus privately-owned, publicly-subsidized housing. Publicly-owned housing in the United States is generally managed by Public Housing Authorities (PHAs). PHAs are created by state or local governments who may oversee the PHA's operations directly or through an appointed board. The Department of Housing and Urban Development (HUD) administers federal funds to PHAs. HUD provides direct federal funds to PHAs for capital improvements on an annual basis. Recently, however, this funding has been significantly decreased and the Obama administration is encouraging increased use of private funds for investments in public housing upgrades.[26] For energy upgrades like PV in publicly-owned housing, funding for a solar

[25] For more information, a study by Mark Bolinger for the Lawrence Berkeley National Laboratory (LBNL), *Financing Non-Residential Photovoltaic Projects; Options and Implications* provides valuable insight into the impact of different financing structures on solar PV economics.

[26] The Obama administration has developed a 'Transforming Rental Assistance' initiative that would alter the way rent is collected in income-restricted properties so that private financing would be more viable for capital improvements in public housing. HUD has submitted the Preservation, Enhancement and Transformation of Rental Assistance Act of 2010 (PETRA) to Congress, which would implement many of these measures. The act is under consideration as of this report writing.

PV investment could come from direct public funding for capital improvements or from private lending institutions. Debt financing products for solar systems, especially smaller systems, are not well developed. That said, there appears to be growing availability of such products.

For privately-owned HUD-assisted properties, which can be private companies or nonprofit organizations, financing for capital improvements can come from a variety of sources, including the property owner's own cash, soft loans from a local housing authority, grants, and in some cases traditional financing sources such as bank loans. Some projects have been partially financed through the New Market Tax Credit (NMTC) Program.[27]

A 2008 Center for American Progress study *Green Affordable Housing* describes the opportunities and challenges affordable housing property owners face when attempting to finance investments in energy improvements such as energy efficiency measures and solar PV. One major challenge is that privately-owned, publicly-subsidized properties are restricted in the amount of dividend that can be distributed to the property owner based on the initial equity investment. This means that property owners may have little economic incentive to increase cash flows generated from a property through energy improvements. Other potential obstacles are regulatory limitations on the use of cash reserves available to HUD-assisted property owners. Relatively large reserves are maintained for HUD-assisted properties that could be made available for solar PV retrofits. However, these reserves are limited, so additional public or private funding is likely to be needed.[28] HUD must approve any loans that are made to HUD-assisted properties, as HUD loans are senior to all other debts on a privately-owned housing project. This may limit access to private loans. Despite these challenges, some property owners have been able to fund solar PV retrofits while maintaining ownership of the system. Many have chosen to develop projects through third-party ownership/financing arrangements.[29]

2.4.2. Third-Party Financing for Solar PV

In a third-party financing arrangement, the PV system is owned by a separate entity who can utilize the tax benefits associated with PV ownership. A "PV project developer" usually acts as an intermediary between the "host customer" (in this case the affordable housing property owner) and the PV system owner who is a "tax equity investor," usually a bank that has the tax appetite to make use of the tax benefits associated with PV ownership. The entity that hosts the PV system pays the PV project developer for the electricity provided for a fixed number of years and may have an option to purchase the system once tax benefits have been realized.

Property owners both within and beyond the affordable housing sector have chosen to install solar through third-party providers for a number of reasons. For one, the high up-front cost of PV can present a significant hurdle for any property owner. Also, for tax-exempt entities such as government agencies and nonprofits, their inability to utilize the federal and state tax benefits associated with PV considerably

[27] The NMTC provides tax credit incentives to investors for equity investments in certified Community Development Entities, which invest in low-income communities. The credit equals 39% of the investment paid out over seven years.

[28] Abramowitz, David, 2008. *Green Affordable Housing: Within Our Reach*, Center for American Progress, p.13.

[29] While a thorough review of existing solar PV retrofits on public housing is beyond the scope of this report, CCSE's review of MASH projects in California and consultations with affordable housing experts indicate that third-party financing in the form of solar power purchase agreements (PPAs) or solar leases are the most common financing method employed in recent years.

increases project costs. Another reason a property owner may choose to invest in solar through a 3rd party provider is keep the responsibility for the PV system's performance with the solar provider who has expertise and experience in maintaining PV systems. Finally, a taxable property owner may not want to lose the ability to deduct electricity expenses from their taxable income. As is explained in Section 2.3.3, the loss of this tax deduction can significantly decrease the value proposition of a host customer-owned PV system.

A number of third-party financing models have been developed. The two dominant financing structures that are in use are power purchase agreements (PPAs) and solar leases. The primary third-party financing options for solar PV are summarized below.

Power Purchase Agreements

Under a PPA, the PPA provider sells power to the customer on a per kWh basis for a set number of years and is responsible for commissioning, operating, and maintaining the PV system performance over the contract term. The PPA provider generally forms either a partnership agreement or a sale/leaseback arrangement with a tax equity investor (often a bank) who can utilize the tax credits associated with owning the PV system. The PPA model is being increasingly used to install solar on affordable housing units.

The key contract criteria generally included in a PPA contract are:

- Price per kWh produced by the PV System
- Price escalation rate - a percent yearly increase in the price per kWh paid to the PPA provider
- Contract length
- Purchase options - generally the greater of fair market value or a minimum price at a given contract year
- Performance guarantees

Solar Leases

Under a solar lease, the lease provider owns the system and leases it back to the host customer for a given period of time, generally at least six years, which allows the leasing company to fully utilize the MACRS depreciation tax benefits.[30] Because solar leases generally leave the performance risk and O&M responsibilities with the customer, this model is not as widely used as the PPA model.[31]

2.4.3. PV Retrofits versus PV on New Construction

A key factor affecting financing of PV on an affordable housing property is whether the system will be part of new construction or a major rehab project, or simply an addition to an existing housing complex. When looking at the economics of solar in new affordable housing construction, there are potential added benefits in terms of cash flow and debt availability that can be provided if the new construction or major rehab is being financed through low-income housing tax credits (LIHTCs). LIHTCs are allocated on a yearly basis in a competitive process.

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[30] In December 2010, the bonus depreciation was modified by the *Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010 (H.R. 4853)*. Under the new rules, eligible property placed in service before January 1, 2012, qualifies for 100% first-year bonus depreciation. For 2012, bonus depreciation is still available, but the allowable deduction reverts from 100% to 50% of the eligible basis. For these years, the value of the tax benefits will be still higher.

[31] Bolinger, Mark, 2009. *Financing Non-Residential Photovoltaic Projects: Options and Implications*, Lawrence Berkeley National Laboratory LBNL-1410E, p. 20.

Global Green, through funding by the California Energy Commission, has developed an online calculator to help affordable housing developers evaluate the cash flow and debt impacts of incorporating solar into new construction or major rehabilitation projects.[32] Our model does not incorporate the impacts of LIHTC financing, as it is focused on PV retrofits on existing buildings.

2.4.4. Funding/Financing Assumptions Used in the Modeling

As described above, funding and financing for solar PV retrofits on affordable housing can come from a variety of sources. How a particular project is funded or financed can have significant implications for project economics. To keep the analysis and interpretation of results manageable in our economic modeling, we simplified the financing structures into four main categories based on tax status and whether the PV system was financed through debt or paid for through cash or equity. Tax status significantly affects project costs due to the tax benefits associated with PV that were described in the previous section. Whether or not a project is debt financed also significantly affects project economics due to the high up-front costs associated with PV ownership. Debt financing reduces that up-front expenditure, but adds interest and debt issuance transaction costs.

We estimated the cost-effectiveness under four financing structures:

- A Taxable System Owner using Cash
- A Taxable System Owner using Debt Financing
- A Tax-Exempt System Owner using Cash
- A Tax-Exempt System Owner using Debt Financing

The discount rates, interest rates and other financial assumptions used in the modeling are summarized in Table 4. For a taxable system owner, we used a discount rate of 8 percent, based on expected returns in the real estate sector.[33] The target rate of return for a third-party solar power provider may differ. Section 5.3 describes how sensitive the cost-effectiveness of a project is to changes in a property owner's discount rate. For a tax-exempt system owner, we used a discount rate of 4.5 percent, reflecting a simplified cost of capital for a government/nonprofit system owner based on a relatively risk-free investment of a US government treasury bill. This cost of capital may be lower if a government or nonprofit property manager uses cash reserves with restricted uses that would not generate returns of 4.5 percent.

We used a 7 percent cost of debt for a taxable system owner as an approximation of current market rates for commercial debt and a 5 percent cost of debt for tax-exempt system owners. While government or nonprofit property owners may have access to lower-cost debt with interest rates below 5 percent, the transaction costs associated with issuing those debts may add to overall financing costs.

2.4.5. Third-Party Ownership, Debt Financing and Transaction Costs

For tax-exempt entities, such as public housing authorities and nonprofits, the inability to utilize the federal and state tax benefits associated with PV considerably increases project costs. As mentioned in the previous section, many tax-exempt entities are entering into solar power purchase agreements or solar leases in order to capture the tax benefits associated with PV ownership.

[32] Global Green's online calculator is available at www.globalgreen.org/solarcalculator
[33] See Appendix C.

An important consideration to keep in mind is that there can be significant transaction costs associated with setting up third-party ownership arrangements. Transaction costs associated with special types of debt financing can also add to the overall cost of a PV system. These costs may be significant and are generally fixed costs that are not very dependent on system size. This means that PPA or solar lease providers may not be willing to pursue projects below a certain size threshold, perhaps 50 kW.[34] That said, our review of MASH Program data and conversations with solar PPA or lease providers indicate that some providers are able to keep transaction costs low enough to pursue smaller projects. These providers do so by having standard contracts, by using creative relationships to utilize the tax benefits of PV, and by aggregating smaller projects into larger contracts.

In addition, CSI data indicate that the transaction costs associated with third-party financing are not markedly different for third-party-owned PV systems compared to systems owned by the host customer. Most of the transaction costs associated with third-party ownership structures should be reported in the cost data available through the California Solar Initiative (CSI) Program's CA Solar Statistics. Upon reviewing this data, we saw no significant difference in reported cost per watt among projects that use third-party financing versus those that do (for commercial sector projects completed in 2010). This suggests that PPA or solar lease providers are able to keep installed costs low enough to keep their overall projects costs (including PPA or lease transaction costs) in line with PV costs for host-owned systems. For example, we assume an installed cost in our modeling of $7.20/Watt-AC based on CSI data (see Table 4).

We accounted for some transaction costs associated with debt financing by assuming a 2.5 percent loan origination fee. Transaction costs for more complicated debt financing sources are not captured in our modeling. When interpreting the results of our modeling, property owners, policy makers and other stakeholders should keep in mind that transaction costs not accounted for in our modeling may reduce the cost-effectiveness of a particular project.

2.4.6. Interpreting the Modeling Results

It is critical to understand how the modeling results should be interpreted given the assumptions about tax status and financing structures that we selected. For government or nonprofit property owners, the metrics reported for "tax-exempt" system owners reflect the cost-effectiveness of PV if the government or nonprofit property owner were to own the PV system. From the perspective of a taxable, private sector property owner, the LCOE reported for "taxable" system owners give an indication of PV's economic performance-assuming that the property owner has the tax appetite to make use of the project's tax benefits. If a taxable property owner is considering owning the PV system, he must consider the impact of losing the tax deduction for electricity expenses (See Section 2.3.3.). This reduces the after-tax value of the electricity offset by the PV system. In our results, we report the LVOS both with and without the loss of the tax deduction. If a property owner chooses not to own the system, but go with a 3rd party PPA or solar lease provider, the PPA or lease payments should remain tax deductible operating expenses.

For both taxable and tax-exempt entities that are considering investing in PV through a third-party provider, the cost metrics reported for the "taxable" system owner gives an indication of the cost that a PPA or solar lease provider would face and what kind of prices a property owner might expect to pay for such an agreement.

[34] Based on consultations with solar PPA providers.

PPAs are usually structured such that the host customer pays the PPA provider a set price per kWh for the electricity produced by the solar system. This price generally escalates over the life of the contract (which can vary from 10-25 years). The levelized value of bill savings (LVOS) can be understood as the breakeven PPA price that the property owner (host customer) could pay (levelized over the contract term at the appropriate discount rate). The levelized cost of energy (LCOE) of a system can be understood as the cost to the PPA provider of producing electricity. If the LCOE of a configuration is considerably lower than the LVOS, then the property owner would have some negotiating room, while recognizing that the PPA provider has to cover transaction costs and may have a higher target rate of return than that used in this analysis (See Section 2.3 and Appendix B for further explanation of the LVOS and LCOE).

2.5. Key Model Assumptions

A number of important assumptions were made in the modeling process that can significantly impact the economics of a site's PV retrofit. These cost, technical, and other assumptions were based on industry data, expert forecasts, and standard best practices. Table 4 outlines key modeling assumptions and information sources. Appendix C provides further details on modeling assumptions used.

Table 4. Summary of key model assumptions

Assumption	Value	Reference
Costs and Incentives		
System Cost	For site-specific modeling: $7.20/Watt-AC	For site-specific modeling: Mean $/W of all completed CSI projects between 5-30kW reserved between June- Dec 2010, a sample size of 773 projects. Cost outliers were removed from the data in accordance with Barbose, G. *et al.*, 2010, where all projects with a $/W (DC) less than $2.00 or greater than $30.00 were excluded. www.californiasolarstatistics.ca.gov
	For generic LCOE modeling: See Section 5.1 Table 16	For generic LCOE modeling: Based on 2010 cost data from California Solar Statistics for different system sizes www.californiasolarstatistics.ca.gov
O&M Costs	Inverter replacement every ten years at a cost of $0.50/Watt-AC	Inverter life span - US DOE: 2008 Solar Technologies Market Report, www1.eere.energy.gov/solar/pdfs/46025.pdf p. 81 Inverter Replacement costs - Referenced to CPUC California Solar Initiative: 2009 Impact Evaluation www.cpuc.ca.gov/NR/rdonlyres/70B3F447-ADF5-48D3-8DF0-5DCE0E9DD09E/0/2009_CSI_Impact_Report.pdf page 2-29
	Other O&M Costs $25/kW-DC	O&M Costs –Draft E3 CSI Single Installation Tool August 2010 www.ethree.com/public_projects/cpuc.html
	Insurance 0.5% of total system cost	Insurance Costs- Bolinger, Mark 2009. *LBNL-1410E* eetd.lbl.gov/ea/emp/re-pubs.html
	Cost inflation	Inflation - Historical average for the U.S. CPI 1990-2009

Assumption	Value	Reference
	2.7% per year	
Utility Electric Rate Escalation	3% annually	CEC: California Energy Demand 2008-2018 Staff Revised Forecast www.energy.ca.gov/2007publications/CEC-200-2007-015/CEC-200-2007-015-SF2.PDF p. 36, and CPUC Rate Charts and Tables – Electricity 2000-2010 www.cpuc.ca.gov/PUC/energy/Electric+Rates/ENGRD/ratesNCharts_elect.htm
Incentive Rate	With MASH- $3.30/W for common area $4.00/W for tenant load offsetting	MASH Program structure, http://docs.cpuc.ca.gov/published/FINAL_DECISION/92455.htm Taxable for federal taxes
Cost Recovery from Tenant Allocation	75% of bill savings recouped in rent adjustment	Consistent with Department of Housing and Urban Development, "Field Office Review Procedure: Energy Performance Contracting" pp. 6-8,and Global Green's Solar Affordable housing Calculator at: www.globalgreen.org/solarcalculator/

PV Production

PV Configuration	180° azimuth 10° tilt	Each site was able to position at this azimuth and the tilt is a reasonable average of what would be found on a pitched roof and a flat roof
PV kW per Sq. Ft	12.51 Watts/Square Foot	Calculated using Roof Ray which is driven by NREL's PV Watts PV production database www.roofray.com
PV Production	1,577 kWh-AC/kW-DC annual production 1,840 kWh-AC/kW-AC annual production	Monthly data from NREL's PV Watts 2 for San Diego, CA mapserve3.nrel.gov/PVWatts_Viewer/index.html Corresponds to a 21% capacity factor Consistent with average capacity factor of monitored systems installed through the California Solar Initiative - See Itron 2010 CSI Impact Evaluation Report page 4-6
DC to AC Derate	.857	Based on average derate factor projects from the CA Solar Initiative Program database for all program years (2007-2010) Data from www.californiasolarstatistics.ca.gov/current_data_files
Productive life span of PV system	25 years	Most PV module manufacturers guarantee the performance of their modules for 25 years
Annual PV system performance degradation	0.5%	Bolinger, Mark (2009) Financing Non-Residential Photovoltaic Projects: Options and Implications Lawrence Berkeley National Laboratory LBNL-1410E eetd.lbl.gov/ea/emp/re-pubs.html

Financial Assumptions		
Discount Rate	8% for Taxable System Owner (Private Sector Property Owner or 3rd party PV system owner)	Private Sector rate based on CAPM Model for Real Estate Sector. See Appendix C Hurdle rate for 3rd party PV system owners may be higher.
	4.5% for Tax-Exempt System Owner (Non-profit or Government Property Owner)	Gov/Nonprofit based on 2010 OMB guidance for discount rate reflecting 20 year T-Bill rates http://www.whitehouse.gov/omb/circulars_a094_a94_appx-c/
Cost of Debt	7% for Taxable System Owner	Based on informal survey of lending institutions that offer solar debt financing products
	5% for Non-Taxable System Owner	Lower rate reflects ability of government/nonprofit entities to access below market-rate debt financing
Tax Rate	Federal 35% State 8.8%	Based on typical federal and CA corporate tax rates
Debt Service Coverage Ratio	1.4	Based on current industry standards
Loan Term	15 Years	Based on review of loan products for solar
Loan to Value Ratio	70%	Based on typical LTV for real estate loan products
Loan Origination Fee	2.5%	Based on typical fees

3. Site Overview and Data Collection

The San Diego Housing Commission (SDHC) provided access to four sites from their portfolio of properties for inclusion in this research. The four sites, Maryland, Georgia, Sycamore-North and El Camino Real, represent a mix of building characteristics, tenant demographics, and physical site constraints. At each site, the project team was given general information about the property and provided access to management and tenants (Table 5).

Table 5. Key characteristics of the four SDHC study sites

MARYLAND	GEORGIA
4131 Maryland St., San Diego, CA 92103	4450 Georgia St., San Diego, CA 92103
Single 3-Story Building, 24 Units	Single 2-Story Building, 8 Units
Common Area Meters: 1	Common Area Meters: 1
Electric Heating	Gas Heating
Tenant Income: 50% of Median Income	Tenant Income: 80% of Area Median Income
Average Unit Occupancy: 94%	Average Unit Occupancy: 96%
SYCAMORE-NORTH	EL CAMINO REAL
281-289 Sycamore Rd., San Diego, CA 92173	12643-12687 El Camino Real, San Diego, CA 92103
Five 2-Story Buildings, 24 Units	Twenty-two 2-story Buildings, 45 Units
Common Area Meters: 4	Common Area Meters: 2
Gas Heating	Gas Heating
Tenant Income: 80% of Area Median Income	Tenant Income: 80% of Area Median Income
Average Unit Occupancy: 95%	Average Unit Occupancy: 97%

To assess project economics, a range of information was collected for each site. At the property level, information on physical characteristics, such as number of units, unit sizes, roof area and layout, mechanical systems specifications, common area meter and load data, was collected, as well as management information, including occupancy rates, tenant income levels, ownership structure and tax status. For each unit, the project team requested 12 months of historic usage, as well as the tariff under which service was being provided; this aspect of the data collection process proved to be a substantial effort.[35] In all, tenant usage data was collected for 35 percent of all possible units, with site-specific collection rates ranging from 20 percent to 50 percent (Table 6).

Two of the sites had significantly more common area load than the other two sites. Maryland and El Camino have an annual common area load of about 20,000-25,000 kWh compared to only about 1,500-4,500 kWh for Georgia and Sycamore. Maryland and EL Camino had significantly higher common area electric bills than the other two sites at about $3,000-$4,000 per year (Table 8). Tenant electric bills were

[35] The collection of tenant account information was by far the most time consuming aspect of the data collection work. The project team spent multiple days on site explaining the project and asking tenants to sign Letters of Authorization (LOA), required for SDG&E to provide historic usage data.

similar across the sites with the exception of El Camino, which had higher per tenant electric use (Table 7).

Table 6. Tenant data collection statistics

Site	% Data Collected	Total Units	Utility Allowance?
Maryland	50%	24	Yes
Georgia	38%	8	Yes
Sycamore-North	46%	24	Yes
El Camino Real	20%	45	N/A

Table 7. Tenant electricity usage and expenditures

Site	Utility Allowance (kWh/yr)	SDG&E Tariff	Annual Usage/Tenant (kWh)				Average Annual Electric Bill ($)
			Mean	St Dev	Min	Max	
Maryland	4,314	DR-LI	2,256	960	1,041	3,845	$230
Georgia	1,937	DR-LI	2,792	644	2,069	3,303	$288
Sycamore-North	2,681	DR-LI	2,150	923	800	3,545	$219
El Camino Real	N/A	DR-LI	3,828	1,215	2,826	6,854	$400

Table 8. Common area electricity expenditures

Site	SDG&E Tariff	Annual Usage (kWh)	Average Annual Electric Bill ($)
Maryland	A	21,781	$3,692
Georgia	DR	1,532	$260
Sycamore-North	DR	4,509	$605
El Camino Real	A	25,150	$4,292

3.1. Maryland

The Maryland complex is located in the University Heights neighborhood of San Diego, in SDG&E's coastal climate zone. It consists of a single three-story building with twenty-four, one-bedroom units. Most of the tenants are elderly or disabled and use the elevator often, resulting in a common area load that accounts for 28% of total building electricity consumption (Table 9), the largest percentage common load among the four sites. The building has a flat, rectangular roof that lends itself to a relatively simple contiguous PV system layout. Taking into account roof obstructions, the building has approximately

2,650 ft^2 of space for a PV array, enough to fit approximately 33 kW-DC of capacity, as shown for illustrative purposes in Figure 5.[36]

Figure 5. Maryland – Site Location and available PV space

Table 9. Maryland - Electricity consumption, common areas versus tenants

	Common Area	Tenants	Total
Consumption (kWh/Year)	21,780	57,398	79,178
Percent of Consumption (%)	28%	72%	100%

3.2. Georgia

The Georgia complex is also located in the University Heights neighborhood of San Diego, in SDG&E's coastal climate zone. It is a relatively small, single-story complex with only eight units. The common area load at this site consists of exterior lighting connected to a single meter; total consumption is minimal, with usage representing only 6 percent of total building load (Table 10). The building has a south-facing pitched roof that has a defunct solar water heating (SWH) system. We would recommend that the property owner evaluate the costs and benefits of installing another SWH system or a combined SWH/PV

[36] Capacity calculations for all four sites assume 100ft^2/1kW and are based on 180° azimuth and 32° array tilt and standard efficiency modules.

system in lieu of a PV only system. The available roof space is approximately 1,050 ft^2. If it were determined that the roof space would be best used for PV, there is enough room for roughly 13 kW-DC of PV capacity (Figure 6).

Figure 6. Georgia – Site location and available PV space

Table 10. Georgia - Electricity consumption, common areas versus tenants

	Common Area	Tenants	Total
Consumption (kWh/Year)	1,532	22,338	23,870
Percent of Consumption (%)	6%	94%	100%

3.3. Sycamore North

The Sycamore North complex is part of a larger, three-site development located on the southern border of San Diego County in San Ysidro. The site consists of five buildings with a total of 24 units. There are four common area meters on the site, one serving a centrally located laundry room and the remaining three serving exterior lighting. The complex is split by a large parking lot, with three buildings on the west side and two buildings plus the laundry room on the eastern end. Three of the site's five buildings have roofs with a south-facing pitch, which in total equal 1,240 ft^2 or 15.5 kW-DC of PV capacity (Figure 7).

Figure 7. Sycamore North - Site location and available PV space

Due to the dispersed layout of the Sycamore site, two separate PV systems would be needed to take advantage of all south facing roof area, each with its own inverter and production meter. We did not consider parking lot solar shade structures in our modeling, as the added costs of such structures did not appear to make economic sense in the context of multifamily affordable housing. Such structures would, however, expand the maximum PV system size available at this site.

Table 11. Sycamore North - Electricity consumption, common areas versus tenants

	Common Area	Tenants	Total
Consumption (kWh/Year)	4,509	51,589	56,098
Percent of Consumption (%)	8%	92%	100%

3.4. El Camino Real

The El Camino Real complex is located in the northern part of the City of San Diego, a few miles inland from the Pacific Ocean. It is the largest site included in this research, with 45 individual units in groups of 3 to 4 per building. Each building has a two-story, townhome style construction and is located around a long central parking area. The site has two common area meters, serving a centrally located laundry room, the manager's office, and exterior lighting.

A large apartment complex is located along the southern edge of the development that significantly shades the complex's southern row of buildings. Because of this, only a portion of the site is suitable for hosting a PV array. In all, there are 1,700 ft^2 of unshaded, south facing roof area at the site, enough to support up to roughly 21 kW-DC of PV capacity (Figure 8). As in the case of Sycamore, the discontinuous nature of the available roof area would require multiple PV systems with separate inverters.

Figure 8. El Camino – Site location and available PV space

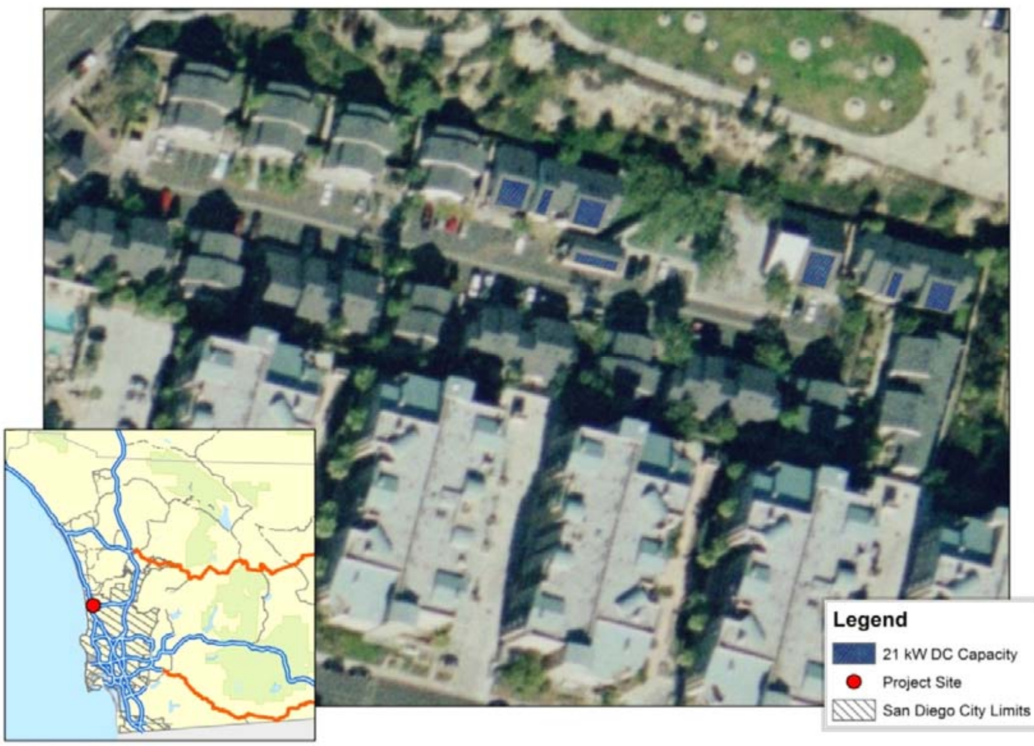


Table 12. El Camino - Electricity consumption, common areas versus tenants

	Common Area	Tenants	Total
Consumption (kWh/Year)	25,150	172,270	197,420
Percent of Consumption (%)	13%	87%	100%

4. Site Results

In this section, we present and examine the economic modeling results of PV retrofit projects at the four study sites. For each site, we modeled multiple system sizes and tenant allocation scenarios and estimated economic return to the system owner under the four scenarios described in Section 2.4.5. These scenarios include the system owner being a taxable entity or a tax-exempt entity and using cash on hand or debt financing. We present results with and without the MASH incentive to illustrate its impact on project economics.

A PV system's economic performance under a 'tax-exempt' system owner would be reflective of costs that the San Diego Housing Commission would experience if the housing commission were to own the project. The economic performance under a 'taxable' system owner would reflect costs to a power purchase agreement (PPA) or solar lease provider, with the understanding that such a provider may have to cover additional transaction and other costs associated with third-party ownership.

For illustrative purposes, we included economic performance metrics for a taxable system owner assuming a loss of the tax deduction that can be claimed for electricity bills (Section 2.3.3). This loss reduces the levelized value of energy savings (LVOS). If the properties examined in this study were owned by a private, taxable property owner, the impact of the loss of this tax deduction would need to be considered if the property owner wanted to own the PV system rather than contract with a 3rd party provider.

Our modeling results should be interpreted as benchmarks of cost-effectiveness. Project-specific costs, financing, target rates of return and other parameters can significantly affect economic performance and should be evaluated before proceeding with a given strategy.

4.1. Maryland

By our estimates, a PV system is economically viable at the Maryland site even without the MASH incentive, if tax benefits are realized. The high value of PV at the site is driven primarily by the complex's relatively large common area load. Maryland's common area consumption is approximately 22,000 kWh per year, nearly 30 percent of total building load (Table 9). This usage is billed at SDG&E's small commercial "A" rate at $0.15-$0.19 per kWh. Tenants at Maryland are on SDG&E's DRLI tariff and all receive CARE discounts, so the monetary value of offsetting tenant load is about $0.10 per kWh.

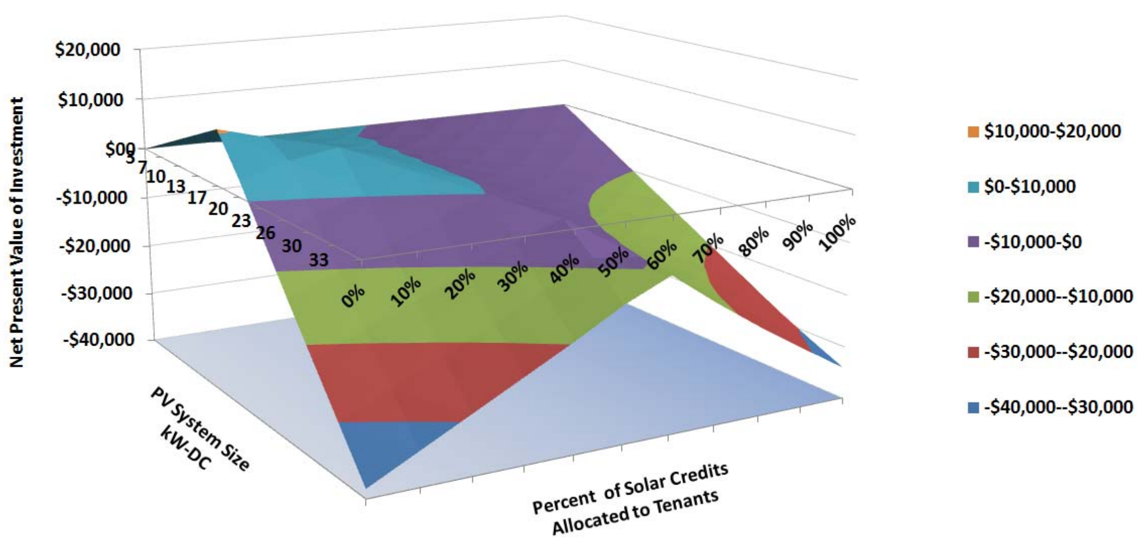
Figure 9 illustrates the tradeoffs at the Maryland site between sizing the system larger and losing some value by offsetting lower priced tenant load up to the maximum PV system size that is feasible at the site, 33 kW-DC. The common area load at Maryland would be offset by a 13 kW-DC system. At this system size, the LVOS is $0.224 and the LCOE is $0.171 for a taxable system owner under debt financing. At system sizes larger than 13 kW, project economics deteriorate, as the margin between the LVOS and LCOE is reduced. In Figure 9, this can be seen by the peak in NPV at 13 kW along the Y-axis. As more solar credits are allocated to tenants (represented by the X-axis), project economic performance deteriorates due to the lower electricity prices paid by tenants. NPV is still positive, however, up to a 23 kW-DC system size with 40 percent of the solar credits allocated to tenants. Under this configuration —

assuming that tax benefits can be utilized and debt financing secured— the system can still break even with both a cost of energy (LCOE) and a value of bill savings (LVOS) of about $0.17 per kWh.

At a PV system size of 23 kW-DC, most of the common area load and about 30 percent of tenant load can be offset. Table 12 shows the economics of such a system under taxable and tax-exempt system owners and with cash purchase versus debt financing. Without the benefits of the tax credits and MACRS depreciation, a system sized to offset a significant portion of tenant load does not appear economically viable. Without the tax benefits - even with the MASH incentive - the LCOE at $0.216-$.227 per kWh is greater than the LVOS at $0.179 per kWh[37], resulting in negative economic return for a 23 kW-DC system. Without the MASH incentive, a tax-exempt property owner like the San Diego Housing Commission would probably be better off contracting with a 3rd party PPA or solar lease provider for this site.

The electricity bill savings to the tenants given a 23 kW-DC system with a 40/60 split of solar credits to tenants/common area meters is about $54 per year per tenant. We assumed that the property owner would be able to recoup 75 percent of this savings through modified utility allowances and rents (see Section 2.1.2), so that would result in limited savings to each tenant of about $14 per year.

Figure 9. Maryland - NPV by system size and allocation to tenant load



Note: For taxable entity under debt financing without MASH incentive, no loss of utility costs tax deduction

37 The LVOS is higher for the tax-exempt system owner due to the lower assumed discount rate.

Table 13. Maryland – Economic performance of a 23 kW-DC system

PV System Size kW-DC	23
PV System Size kW-AC	19.7
Installed Cost ($/W-AC)	7.2
Total Installed Cost ($)	141,840
Percent Solar Credits to Tenants	40%
Percent Common Area Load Offset	90%
Percent Tenant Area Load Offset	27%
Year 1 Savings on CA Meter ($)	3,692
Year 1 Savings on Tenant Meters (avg $ per tenant)	62

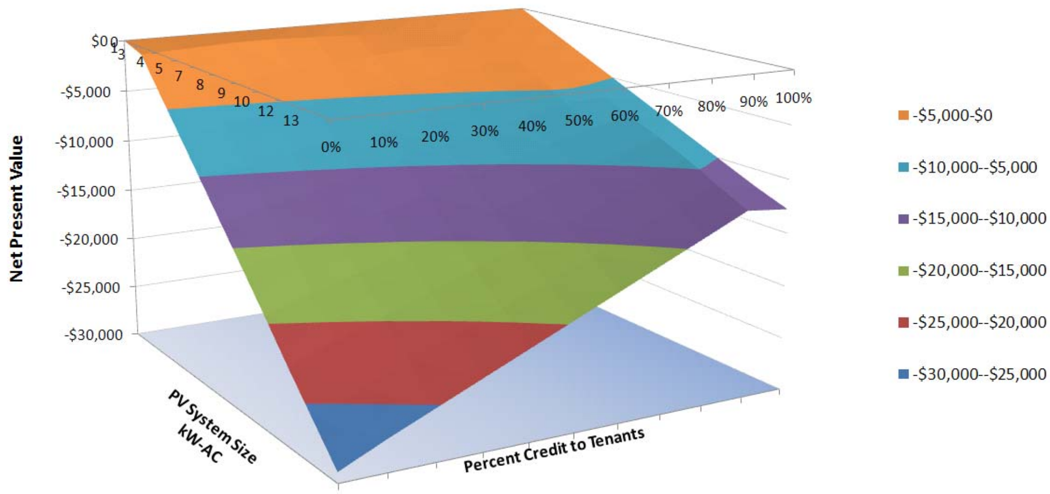
	Taxable System Owner				Tax-Exempt System Owner	
	100% Cash		Debt Financed		100% Cash	Debt Financed
No MASH Incentive	No Loss of Tax Ded.	With Loss of Tax Ded.*	No Loss of Tax Ded.	With Loss of Tax Ded.*		
LCOE ($/kWh)	0.208		0.171		0.348	0.359
LVOS ($/kWh)	0.171	0.117	0.171	0.117	0.179	0.179
NPV ($)	-12,600	-31,000	100	-18,200	-82,600	-88,000
With MASH Incentive						
LCOE ($/kWh)	0.103		0.067		0.216	0.227
LVOS ($/kWh)	0.171	0.117	0.171	0.117	0.179	0.179
NPV ($)	11,800	4,800	24,100	17,600	-18,000	-23,600

*See section 2.3.3 and 2.4.6

4.2. Georgia

The Georgia site has available roof space for up to a 13 kW-DC PV system. Without the MASH incentive, project economics at the Georgia site are not favorable at any combination of system size and common area/tenant allocation according to our model estimates (Figure 10). The common area load is so small at the Georgia site (about 1,500 kWh per year or 6 percent of building load) that the minimum system size eligible through the CSI program (1 kW) would offset slightly more than the common area load. Not only is the common area load small, but the common area meter is on the residential DR tariff and consumption is in the lower priced tiers of that tariff. A system designed to offset common area load would not break even with an NPV of about -1,000. The low consumption and electricity prices paid by the tenants at Georgia make offsetting tenant load also economically challenging. As with the Maryland site, tenants are on the discounted DRLI tariff.

Figure 10. Georgia - NPV by system size and allocation to tenant load



Note: For taxable entity under debt financing without MASH incentive, no loss of utility costs tax deduction

Table 14 shows the estimated economic performance for a PV system at Georgia at the maximum possible system size of 13 kW-DC, with 95% of the solar credits allocated to tenants. Such a system would offset about 90 percent of tenant area load and 70 percent of common area load. According to our estimates, such a project would only break even with a MASH incentive and assuming that tax benefits can be utilized. The cost of energy (LCOE) under this scenario would be about $0.05 -$0.09 per kWh and the value of bill savings (LVOS) would be about $0.10 per kWh.

Because there are only 8 units at the site, a 13 kW PV system would generate solar credits that could offset a significant portion of tenant load. Average annual savings on tenant electricity bills is $250 with such a system. With 75 percent of that savings going to pay for the cost of the system, tenants would pocket about $60 per year.

Table 14. Georgia - Economic performance of a 13 kW-DC system

PV System Size kW-DC	13
PV System Size kW-AC	11.2
Installed Cost ($/W-AC)	7.2
Total Installed Cost ($)	80,640
Percent Solar Credits to Tenants	95%
Percent Common Area Load Offset	70%
Percent Tenant Load Offset	90%
Year 1 Savings on CA Meter ($)	138
Year 1 Savings on Tenant Meters (avg $ per tenant)	250

	Taxable System Owner				Tax-Exempt System Owner	
	100% Cash		Debt Financed		100% Cash	Debt Financed
No MASH Incentive	No Loss of Tax Ded.	With Loss of Tax Ded.*	No Loss of Tax Ded.	With Loss of Tax Ded.*		
LCOE ($/kWh)	0.208		0.170		0.348	0.356
LVOS ($/kWh)	0.103	0.099	0.103	0.099	0.108	
NPV ($)	-20,500	-21,200	-13,100	-13,800	-66,900	-69,200
With MASH Incentive						
LCOE ($/kWh)	0.092		0.054		0.202	0.210
LVOS ($/kWh)	0.103	0.099	0.103	0.099	0.108	
NPV ($)	2,000	1,400	9,400	8,800	-26,200	-28,500

*See section 2.3.3 and 2.4.6

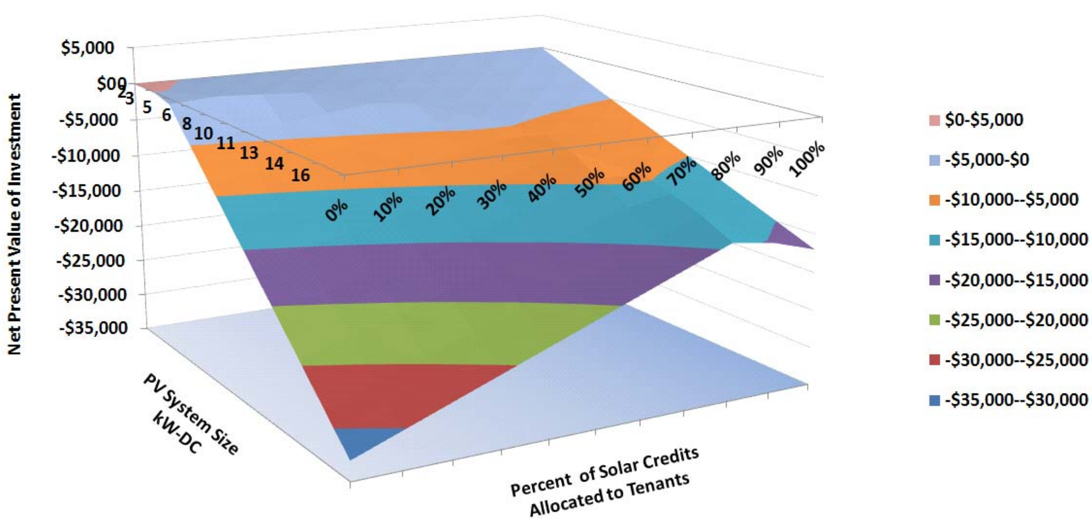
4.3. Sycamore North

Similar to the Georgia site, the economics of a PV retrofit at Sycamore North are not particularly favorable at any system size and common area/tenant allocation of solar credits - without the MASH incentive (Figure 11). The value of the offset energy is relatively low, as the common area meters are on SDG&E's DR rate and consume below the baseline allocation from SDG&E (Figure 12). This means that electricity for the common area meters is purchased at about $0.13 per kWh.

Tenant meters are on the low-income DRLI rate and also receive a CARE discount, so the value of avoided electricity payments is also relatively low for tenants. The Sycamore North site faces an additional challenge in system design compared to the Maryland and Georgia sites due to its layout, which requires a split system with two inverters to take full advantage of available roof space. This may increase system costs compared to sites like Maryland and Georgia that have contiguous roof space available for a PV system.

Without the MASH incentive, the project just breaks even in terms of positive NPV at a system size of about 1.5 kW, where 50 percent of common area load is offset. With this configuration, savings on the common area electricity bill is $317 per year.

Figure 11. Sycamore North - NPV by system size and allocation to tenant load



Note: For taxable entity under debt financing without MASH incentive, no loss of utility costs tax deduction

The largest rooftop PV system that would be viable at the site would be sized at 15 kW-DC. Such a system - with 85 percent of solar credits allocated to tenants and 15 percent to the common area meters - would offset about 80 percent of common area load and 40 percent of tenant load. This system configuration would only be economically viable with the MASH incentive and if tax benefits can be utilized, with an LCOE of $0.05 - $0.09 per kWh and an LVOS of about $0.10 -$0.11 per kWh. The annual savings to tenant meters with such a configuration would be about $80 per year. With 75 percent of that going to the property owner for cost recovery of the investment, the annual savings to a given tenant is about $20 per year.

Figure 12. Sycamore North-Common area meter usage and baseline allocation

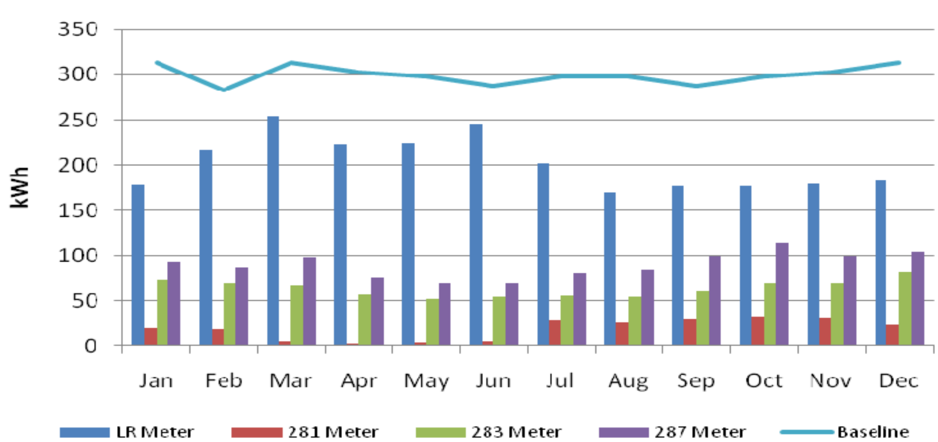


Table 15. Sycamore - Economic performance of a 15 kW-DC system

PV System Size kW-DC	15
PV System Size kW-AC	12.9
Installed Cost ($/W-AC)	7.2
Total Installed Cost ($)	92,880
Percent VNM Credits to Tenants	85%
Percent Common Area Load Offset	80%
Percent Tenant Load Offset	40%
Year 1 Savings on CA Meters ($)	477
Year 1 Savings on Tenant Meters (avg $)	86

	Taxable System Owner				Tax-Exempt System Owner	
	100% Cash		Debt Financed		100% Cash	Debt Financed
No MASH Incentive	No Loss of Tax Ded.	With Loss of Tax Ded.*	No Loss of Tax Ded.	With Loss of Tax Ded.*		
LCOE ($/kWh)	0.208		0.170		0.348	0.356
LVOS ($/kWh)	0.110	0.099	0.110	0.099	0.115	
NPV ($)	-22,000	-24,400	-13,600	-15,900	-74,700	-77,400
With MASH Incentive						
LCOE ($/kWh)	0.094		0.057		0.204	0.213
LVOS ($/kWh)	0.110	0.099	0.110	0.099	0.115	
NPV ($)	3,500	1,100	11,900	9,700	-28,700	-31,400

*See section 2.3.3 and 2.4.6

4.4. El Camino Real

Similar to the Maryland site, El Camino Real has a significant common area load of about 25,000 kWh per year. This is the primary driver of PV retrofit value at the site, as the common area meters are on SDG&E's "A" tariff with rates of $0.15-$0.19 per kWh. As with the other sites, tenant load is served on the discounted DRLI tariff with a CARE discount, so tenants pay about $0.10 per kWh for electricity.

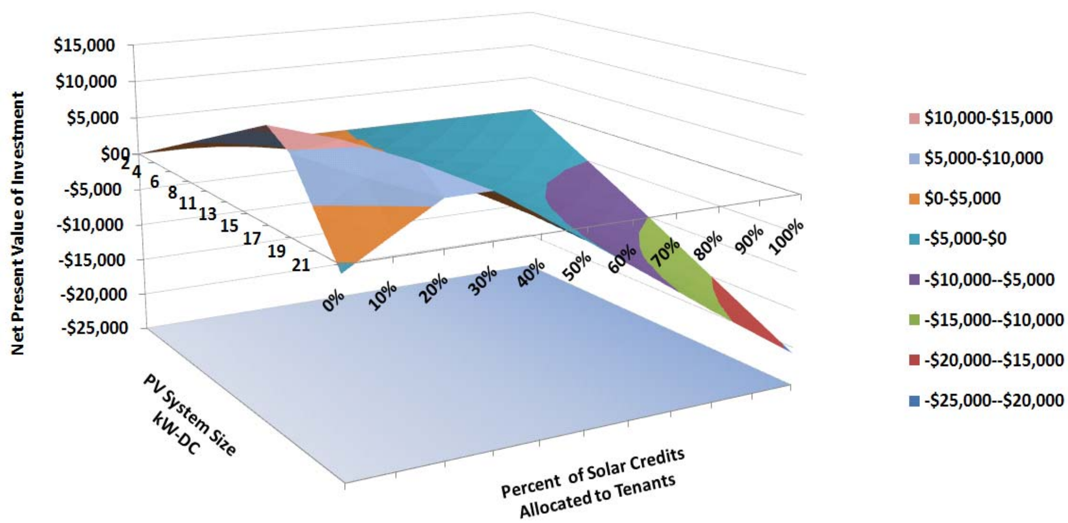
Figure 13 shows the relationship between system size, the solar credit allocation to tenants, and project NPV. The two peaks on the X and Y axes of the figure can be explained by the following: on the Y axis - which shows system size in kW-DC, we see that at about 15 kW, all the higher priced common area load is offset, so economic performance declines past this point as PV capacity is dedicated to offsetting lower-priced tenant load; on the X axis — which represents the percent of solar credits allocated to tenants — economic performance declines if more than 30% of the maximum system size of 21 kW is allocated to tenant area load, as lower priced tenant load is offset rather than higher priced common area load.

The El Camino Real site is space-constrained and unable to meet anywhere near the site's total building load with the roof area available for PV, which is large enough for a system size of 21 kW-DC. For a 21 kW system with 30 percent of credits allocated to tenants, only six percent of tenant load is offset and the savings on tenant electricity bills is low, at about $24 per tenant per year. It may not be worth the transaction costs of establishing a mechanism to generate cash flow from the tenant savings. Without cash flow from the tenants, a 21 kW system would not be economically viable. A 15 kW system designed only to offset common area load would be economically viable and would avoid the need to establish such a mechanism.

A 15 kW-DC system that would offset most of the common area load would produce positive economic returns by our estimates if tax benefits are captured — even without the MASH incentive. Our model estimates an LCOE for such a system of $0.17-$0.21 per kWh (Table 15). The value of the bill savings (LVOS) is $0.225 per kWh. Because the San Diego Housing Commission who owns the property is not a taxable entity — without the assistance of a MASH incentive — it would probably make economic sense for SDHC to contract with a 3rd party provider,.

For illustrative purposes, we see that the LVOS at the site for a 15 kW system is only $0.133 per kWh with the loss of the tax deduction, less than the LCOE. If the property owner were a taxable entity, the loss of this tax deduction would result in negative economic return, with project NPV of about -$17,000 to -$9,000 depending on cash or debt financing.

Figure 13. El Camino Real - NPV by system size and allocation to tenant load



Note: For taxable system owner, under debt financing, without MASH incentive, no loss of utility costs tax deduction

Table 16. El Camino Real- Economic performance of a 15 kW-DC system

PV System Size kW-DC	15
PV System Size kW-AC	12.9
Installed Cost ($/W-AC)	7.2
Total Installed Cost ($)	92,880
Percent VNM Credits to Tenants	0%
Year 1 Savings on CA Meters ($)	4,100
Year 1 Savings on Tenant Meters (avg $)	0

	Taxable System Owner				Tax-Exempt System Owner	
	100% Cash		Debt Financed		100% Cash	Debt Financed
No MASH Incentive	No Loss of Tax Ded.	With Loss of Tax Ded.*	No Loss of Tax Ded.	With Loss of Tax Ded.*		
LCOE ($/kWh)	0.208		0.171		0.348	0.361
LVOS ($/kWh)	0.224	0.133	0.224	0.133	0.235	
NPV ($)	3,800	-16,800	12,000	-8,600	-36,200	-40,500
With MASH Incentive						
LCOE ($/kWh)	0.112		0.075		0.226	0.240
LVOS ($/kWh)	0.224	0.133	0.224	0.133	0.235	
NPV ($)	25,400	4,800	33,700	13,000	2,800	1,500

*See section 2.3.3 and 2.4.6

5. Generic Cost-Effectiveness Modeling Results

We designed the modeling tool for this study to examine the value of PV retrofits at the four study sites located within the San Diego Gas and Electric (SDG&E) service territory. The tool can also be used to develop generic cost estimates that can then be used to benchmark the cost of PV against electricity rates in other California utilities that would be applicable in the affordable housing sector. In this section, we provide levelized cost of energy (LCOE) estimates for PV retrofits and compare these estimates to residential and commercial utility rates across the state's three major investor owned utilities (IOUs): Southern California Edison, Pacific Gas and Electric (PG&E) and SDG&E. Electricity usage in the three IOUs represents about 70 percent of the state's electricity consumption, so this comparison is relevant to a good portion of California's electricity consumers. An important caveat, however, is that our PV production assumption of 1,557 kWh-AC/kW-DC (21% AC capacity factor) is probably higher than what would be experienced in Northern California. Therefore, LCOE estimates might be underestimated for these areas.[38]

5.1. System Costs and System Size

The four sites we analyzed for this study had available rooftop capacity for relatively small PV systems, less than 35 kW-DC. Larger multifamily complexes could install significantly larger systems. Within California's MASH Program, PV systems as large as 550 kW-DC have been installed. Because installed PV system costs decrease as project capacity increases, we varied average costs by system size. Table 16 summarizes the total installed cost per Watt-AC inputs that we used for the generic cost-effectiveness modeling. These costs were based on cost per CEC-AC Watt reported through the California Solar Initiative.

Table 17. Average total cost per Watt-AC for installed projects in CA, Aug 2009-Aug 2010

System Size (kW)	Avg $/Watt	SD	N
<10	8.7	2.9	6,439
10-99	7.2	1.6	366
300+	6.6	1.0	6

Source: California Solar Statistics download, September 2, 2010

5.2. LCOE Modeling Results

Table 18 and Table 19 summarize the results of the generic LCOE modeling: Table 18 shows LCOE without the MASH incentive and Table 19 shows LCOE with the MASH incentive (at $3.30/Watt-AC). According to our model, the MASH incentive reduces project costs by about $0.10 per kWh for a taxable system owner and $0.12 per kWh for a tax-exempt system owner.

As we would expect, the LCOE is considerably lower for a system owner that can utilize the tax benefits associated with PV than for a tax-exempt entity. With the MASH incentives, our model estimates an

[38] The 2010 Itron CSI Impact Evaluation report looked at actual PV production in the three major CA IOU territories and found AC capacity factors ranging from a low of 20.6% in PG&E territory to 21.2% in SCE territory. Page 4-6.

LCOE as low as about $0.10-$0.15 per kWh with up-front cash payment depending on system size and assuming that tax benefits are utilized. For tax-exempt system owners, our LCOE estimates are at about $0.20-$0.29 per kWh with upfront cash payment and the MASH incentive. Without the MASH incentives, we estimate costs for taxable entities at about $0.20-$0.25 per kWh and at about $0.32-0.41 per kWh for tax-exempt entities depending on system size.

The cost for a taxable system owner is lower under a debt financing scenario because of both the reduced up-front costs and the debt interest tax shield. Under this scenario, costs are about $0.06-$0.11 per kWh with the MASH incentive and $0.16-0.20 per kWh with no incentive. In contrast, for a tax-exempt system owner, the LCOE is higher with debt financing by our estimates. Debt financing at the interest rate we chose (5%) doesn't reduce costs for the tax-exempt system owner due to a lower discount rate (4.5%) and the lack of an interest tax shield. In fact, in our model, debt financing for the tax-exempt system owner increases LCOE slightly due to loan fees, interest, and the costs of maintaining a debt-service reserve fund.

We benchmarked our LCOE modeling results against other studies and modeling tools outlined in Section 1.6. We found that our estimates are generally in line with modeling done by other researchers, though differences in key input assumptions can make direct comparisons difficult. Our LCOE estimates are slightly lower than other estimates primarily because we assumed a relatively high first year PV capacity factor of 21 percent. This capacity factor is in line with CSI project performance data for 2010[39] and the production we estimated through NREL's PV Watts calculator. As more performance monitoring data is collected for PV projects over multiple years, better information on expected PV production will help refine future LCOE modeling.

[39] Itron 2010 CPUC CSI Impact Evaluation Report page 4-6.

Table 18. PV LCOE by system owner and financing type *without MASH incentive*

		Levelized Cost of Energy (LCOE) $/kWh			
		Taxable System Owner		Tax-Exempt System Owner	
System Size kW-AC	$/Watt-AC	100% Cash	Debt Financed	100% Cash	Debt Financed
5	$8.7	0.246	0.201	0.411	0.428
30	$7.2	0.208	0.171	0.348	0.356
300	$6.6	0.192	0.158	0.322	0.333

Notes: Assumes ITC Credit and MACRS tax benefits are realized for taxable system owner. AC Capacity Factor of 21%. Cost estimate by system size based on 2009 and 2010 data from California Solar Statistics.

Table 19. PV LCOE by system owner and financing type *with MASH incentive at $3.30/Watt-AC*

		Levelized Cost of Energy (LCOE) $/kWh			
		Taxable System Owner		Tax-Exempt System Owner	
System Size kW-AC	$/Watt-AC	100% Cash	Debt Financed	100% Cash	Debt Financed
5	$8.7	0.150	0.105	0.290	0.307
30	$7.2	0.112	0.074	0.226	0.234
300	$6.6	0.096	0.063	0.201	0.211

Notes: Assumes MASH incentive at 3.30 per Watt-AC. ITC Credit and MACRS tax benefits are realized for taxable system owner. AC Capacity Factor of 21%. Cost estimate by system size based on 2009 and 2010 data from California Solar Statistics.

5.3. Sensitivity Analysis

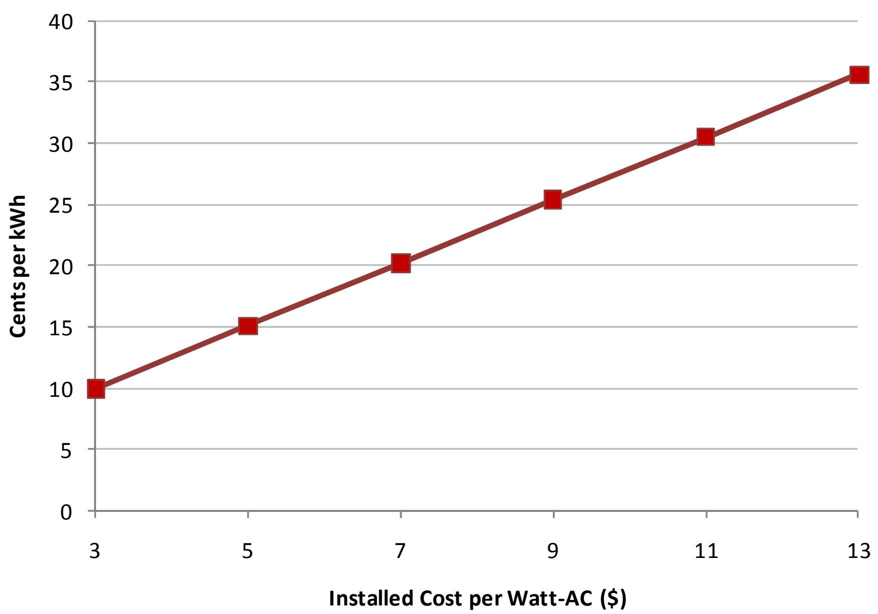
Levelized cost of energy calculations can be highly sensitive to certain inputs. It is critical when interpreting LCOE outputs that consideration be given to assumptions that underpin the model and how changes in those assumptions might affect LCOE. In this section, we evaluate how LCOE is affected by three key input variables:

1) Installed System Cost
2) Discount Rate
3) Cost of Debt

To examine the effect of installed cost per watt and the discount rate on LCOE, we modeled a taxable system owner assuming up-front cash payment. To evaluate the sensitivity of LCOE to the cost of debt, we modeled the impact on a taxable system owner assuming 70 percent debt financing of the system.

Figure 14 shows how the LCOE changes with a change in installed cost per Watt-AC holding other variables constant. According to our model, the LCOE decreases by about $0.05 per kWh for every two dollar decrease in installed cost per Watt-AC for a taxable system owner.

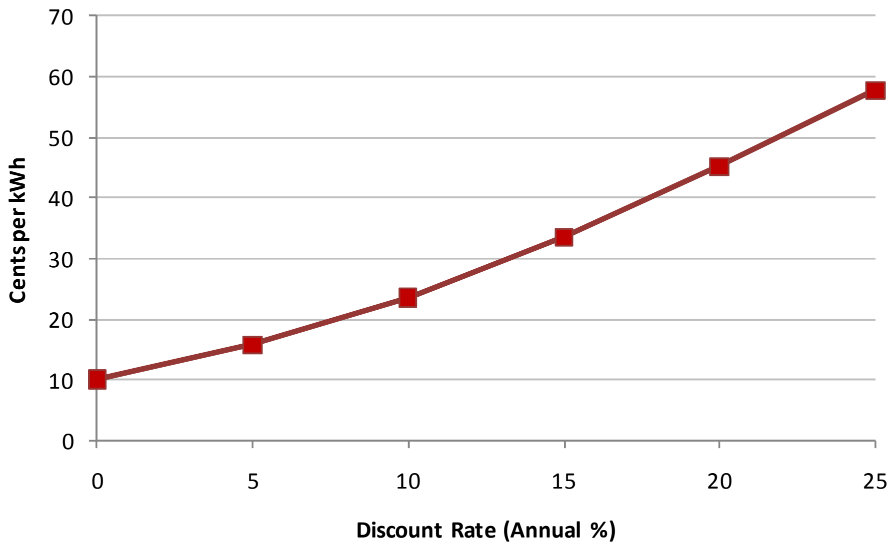
Figure 14. Sensitivity of LCOE to installed cost per Watt



Notes: Assumes cash financed, 8% discount rate, taxable system owner, no cash incentive, ITC and MACRS utilized, 21% AC Capacity Factor. See Table 4 for additional assumptions

Figure 15 shows the sensitivity of the LCOE to the nominal discount rate as estimated by our model. The LCOE is quite sensitive to the discount rate. For example, a change in the assumed rate from 5-10 percent changes the LCOE by about $0.08 per kWh. The 8 percent discount rate we used in our model is based on our best estimation of expected return for the real estate sector in general (see Appendix C), but it is important to keep in mind that for a given project, the discount rate may be different depending on the system owner's specific expectations of financial return. This can significantly change the estimated LCOE for a particular project.

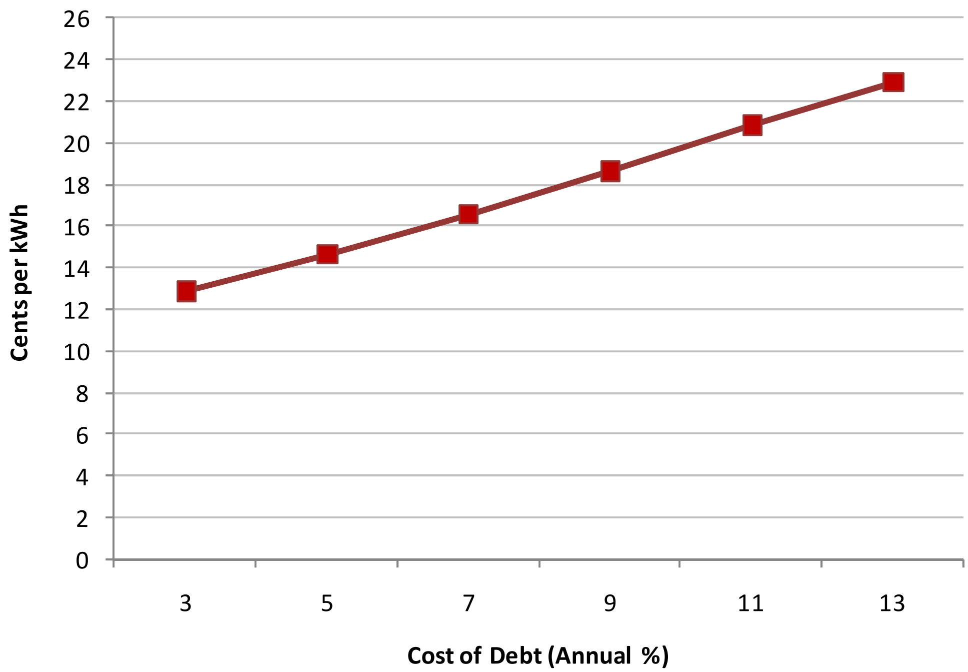
Figure 15. Sensitivity of LCOE to discount rate



Notes: Assumes cash financed, $7.00/Watt-AC, taxable system owner, no cash incentive, ITC and MACRS utilized, 21% AC Capacity Factor. See Table 4 for additional assumptions.

Figure 16 shows the sensitivity of LCOE to the cost of debt for a taxable entity holding other variables constant. According to our model, the LCOE increases by approximately $0.02 per kWh for every 2 percentage point increase in the cost of debt within the range of probable debt interest rates. We assumed a cost of debt of 7 percent for taxable entities and 5 percent for tax-exempt entities for our site-specific and generic modeling of PV economics. For a particular project, more or less favorable financing arrangements can appreciably affect the estimated LCOE for the project, though LCOE is not as sensitive to changes in the cost of debt as it is to the installed cost per watt or discount rate assumed in the model.

Figure 16. Sensitivity of LCOE to cost of debt



Notes: Assumes $7.00/Watt-AC, 8% discount rate, taxable system owner, no cash incentive, ITC and MACRS utilized, 21% AC Capacity Factor. See Table 4 for additional assumptions.

5.4. LCOE versus CA IOU Rates

As is discussed in Section 2.1, if the LCOE of producing electricity with onsite PV is less than the price that a property owner would have paid to the utility for that electricity, then the property owner will realize a positive economic return from investing in PV. It is important to keep in mind, however, that current utility rates are not a measure of the *levelized* value of bill savings (LVOS) over the course of the life of a system, because utility rates are not likely to stay constant for 25 years, and because a PV system's performance will degrade over its useful life, which reduces the amount of energy offset. For example, if a property owner is paying $0.18 per kWh today, then over 25 years, the LVOS is about $0.24 per kWh, assuming a discount rate of 8 percent, a PV performance degradation rate of 0.5 percent and an annual utility rate escalation of 3 percent per year.

5.4.1. Offsetting Tenant Load

Most affordable housing tenants in the three major CA IOUs will be served on special residential tariffs that are available only to low-income customers. Many customers will also utilize the California Alternate Rates for Energy (CARE) discount that reduces the electricity charges portion of the bill by as much as 20 percent. Residential tariffs in the CA IOUs are volumetrically tiered, with higher prices paid for consumption over designated levels. Tier 1 and 2 prices on low-income tariffs range from $0.08 to $0.15 per kWh (Table 20).

We estimated LVOS for generation dedicated to offsetting tenant load at about $0.10 per kWh for the sites we analyzed where tenants were served on SDG&E's low income DR-LI tariff and received CARE discounts.

By our estimates, the LCOE of a PV system without cash incentives is about $0.16-$0.25 per kWh, depending on system size and financing for a taxable system owner, and $0.32- $0.43 per kWh for a tax-exempt system owner. Therefore, a PV system designed to offset low-income tenant load does not appear to be cost competitive with utility rates. A PV project designed to offset tenant load would have to receive some form of subsidies, such as grants or cash rebates (like the MASH incentive).

5.4.2. Offsetting Common Area Load

The value of common area solar credits can vary widely based on the particular tariff that the common area meter is on and the time-of-use consumption patterns for that meter. Commercial tariffs are complex and may include demand charges on top of per unit of energy charges (Table 21). Some commercial tariffs vary pricing with the time of day and season. If electricity is being used during peak hours, electric rates can be as high as $0.45 per kWh. Most moderately-sized housing complexes will be on small commercial rates in the three major CA investor owned utilities, such as the "A," "GS-1" and "A-1-A" rates which are flat, seasonally adjusted tariffs available to small commercial users. These rates range from $0.14-0.20 per kWh depending on the season and represent LVOS values of about $0.18-$.026 per kWh.[40]

Some housing complexes may be large enough to qualify for commercial tariffs required for larger utility customers. Rates for larger commercial customers are approximately $0.11-$0.18 per kWh in the three major CA IOUs, though this can vary significantly depending on a customer's particular electricity load profile. This corresponds to an LVOS of about $0.14-$0.24 per kWh.

The LCOE we estimate for a taxable system owner without MASH incentives is $0.16-$0.25 per kWh. Thus, PV retrofits appear to be cost-competitive with higher end commercial utility rates in the CA IOUs, even without the MASH incentives. For a tax-exempt system owner, however, our estimated LCOE of $0.32- $0.43 per kWh is not cost-competitive with commercial rates.

[40] Assuming a discount rate of 8 percent, a PV performance degradation rate of 0.5 percent and an annual utility rate escalation of 3 percent per year. No loss of utility tax deduction.

Table 20. Residential tariffs across California's three largest IOUs

IOU		Residential Tariff Structures			
		Volumetric Tiered w/ Seasonal Variation	Volumetric Tiered w/Seasonal Variation and Low Income Discount	Seasonal Variation, No Tiers	Tiered Time of Use Rates w/Seasonal Variation
SDG&E	*Tariff Name*	DR	DR-LI	No Open Tariff	DR-TOU
	Requirements	Domestic Residential	Qualifying Low- Income Domestic Residential	N/A	Domestic Residential
	Rates	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 –$0.27-0.28 Tier 4 –$0.29-0.30	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 – $0.21-0.22 Tier 4 – $0.21-0.22	N/A	Tier 1 – $0.14 Tier 2 – $0.14 Tier 3 – $0.24-0.28 Tier 4 – $0.28-0.40
SCE*	*Tariff Name*	D	D-CARE	TOU-D-1&2	TOU-D-T
	Requirements	Domestic Residential	Qualifying Low- Income Domestic Residential	Domestic Residential	Domestic Residential
	Rates	Tier 1 – $0.13 Tier 2 – $0.15 Tier 3 – $0.24 Tier 4 – $0.28 Tier 5 – $0.31	Tier 1 – $0.09 Tier 2 – $0.11 Tier 3 – $0.18 Tier 4 – $0.18 Tier 5 – $0.18	TOU-D-1 – $0.17-0.42 TOU-D-2 – $0.15-0.34	Tier 1 - $0.12-0.20 Tier 2 - $0.22-0.54
PG&E	*Tariff Name*	E-1	EL-1	No Open Tariff	E-6
	Requirements	Domestic Residential	Qualifying Low- Income Domestic Residential	N/A	Domestic Residential
	Rates	Tier 1 – $0.12 Tier 2 – $0.14 Tier 3 – $0.29 Tier 4 – $0.40 Tier 5 – $0.40	Tier 1 – $0.08 Tier 2 – $0.10	N/A	Tier 1 – $0.09-0.30 Tier 2 – $0.11-0.32 Tier 3 – $0.26-0.47 Tier 4 – $0.37-0.58 Tier 5 – $0.37-0.58

* SCE generation charges are calculated using a percentage of energy supply from DWR sources, which change daily.

Table 21. Commercial tariffs across California's three largest IOUs

IOU		Commercial Tariff Structures*: Flat Rates w/ Seasonal Variation	Flat Rates w/Seasonal Variation and Demand Charges	Time of Use Rates w/Seasonal Variation	Time of Use Rates w/Seasonal Variation and Demand Charges
SDG&E	*Tariff Name*	A	No open tariff	No open tariff	AL-TOU
	Requirements	Demand ≤ 20kW	N/A	N/A	Demand > 20 kW
	Rates	$0.15/kWh-$0.19/kWh	N/A	N/A	Energy Charges** ($0.08/kWh-$0.11/kWh) Demand Charges** ($5.00/kW-$13.00/kW)
SCE	*Tariff Name*	GS-1	GS-2	TOU GS-1	GS-2-A or TOU-GS-3-A,B, or CPP
	Requirements	Demand ≤ 20kW	Demand >20 and ≤ 200kW	Demand ≤ 20kW	Demand >20 and ≤ 200kW for GS-2 Demand >200 and ≤ 500kW for GS-3
	Rates	$0.14/kWh-$0.19/kWh	Energy Charges** $0.08/kWh-0.09/kWh Demand Charges ** $12.00/kW-$19.00/kW	$0.11/kWh$-$0.38/kWh	Energy Charges** GS-2-A/B $0.07/kWh $-0.34/kWh TOU-GS-3 A/B/CPP $0.06/kWh -$0.26/kWh) Demand Charges** $0.00/kW-$16.00/kW
PG&E	*Tariff Name*	A-1-A	A-10-Non-TOU	A-1-B & A-6	A-10
	Requirements	Demand <200 kW	Demand <200kW	Demand <200kW for A-1 Demand ≤499kW for A-6	Demand ≤499 kW
	Rates	$0.14/kWh-$0.20/kWh	Energy Charges ** $0.11/kWh-$0.14/kWh Demand Charges** $6.00/kW-$11.00/kW	A-1-B $0.14/kWh -0.22/kWh A-6 $0.12/kWh -0.45/kWh	Energy Charges** $0.10/kWh -$0.16/kWh Demand Charges** $6.00/kW-$11.00/kW

*Probable common area meter usage limited to less than 500 kW per month.

**The blended per kWh rate paid by customers whose tariffs include demand charges is determined by the customer's total kWh usage and the customer's kW demand. The blended rate is defined as the annual bill divided by the annual kWh usage. Different customers have different load profiles -energy usage and demand- and so will pay different blended rates per kWh. Based on our modeling of tariff structures for clients in the three major CA IOUs, we find that demand charges generally add about $0.05-$0.10 per kWh to the energy charges applicable on a given tariff. Wiser et. al. (2007) found that demand charges add approximately $0.03/kWh-$0.10/kWh to energy charges in a study of commercial utility customers in California. See: Wiser, R., Mills, A., Barbose, G. and Golove, W. (2007) The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California. *LBNL-63019* p. 25

6. Findings

Our economic modeling and examination of four San Diego Housing Commission housing complexes provides insight into the cost and value of PV retrofits in the context of affordable housing and VNM's effectiveness in improving project economics. We found that:

1. Multifamily affordable housing PV retrofits are most cost-effective in properties where there are sizable common area loads. Without an incentive such as the MASH rebate, offsetting tenant load with PV is economically challenging.
2. VNM enables property owners with sufficient common area load to invest in PV capacity that offsets tenant load while maintaining the economic viability of the project
3. PV retrofits can generate meaningful utility bill savings to tenants, but a significant portion of those savings would need to be shared with property owners to make systems economically viable
4. The economic performance of PV retrofit projects on affordable housing improves significantly if tax benefits are utilized

6.1. Offsetting Common Area Loads is Most Cost-effective

Affordable housing complexes generally have a meter that captures electricity use in shared or 'common' areas. Outdoor lighting, laundry facilities, office space, and mechanical systems such as elevators create common area load. The property owner usually pays the electric bill for this load which may be served on commercial or residential electricity tariffs. Each tenant unit usually has its own meter which is served on a residential tariff. The cost of a PV retrofit must thus be measured against both commercial and residential electricity rates.

Commercial rates vary significantly by tariff and customers' particular load profiles. For small commercial customers, rates are about \$0.14-\$0.20 per kWh in the three largest CA IOUs (Table ES-3). Rates for larger commercial customers (demand >20 kW and <500 kW) are approximately \$0.11-\$0.18 per kWh, though this can vary significantly depending on a customer's particular electricity load profile.[41] Higher tier residential rates can be as high as \$0.24-\$0.58 per kWh (Table ES-4). Low-income residential tenants in the CA IOU territories pay considerably less for electricity at about \$0.08-\$0.15 per kWh, as they generally consume in the lower tiers of electricity tariffs, are on low-income discounted rates (Table ES-4) and often receive additional California Alternative Rates for Electricity (CARE) discounts.

It is important to keep in mind, however, that current utility rates are not a measure of the *levelized* value of bill savings (LVOS) over the course of the life of a system, because utility rates are not likely to stay constant into the future, because future cash flows should generally be discounted, and because a PV

[41] Large commercial electricity tariffs in the three major CA IOUs often include both charges for the customer's total kWh usage and the customer's kW demand. The blended per kWh rate paid by customers whose tariffs include demand charges is determined by the customer's specific load profile. The blended rate is defined as the annual bill divided by the annual kWh usage.

system's performance will degrade over its useful life, which reduces the amount of energy offset. For example, if a property owner is paying $0.18 per kWh today, then over 25 years, the LVOS is about $0.24 per kWh, assuming a discount rate of 8 percent, a PV performance degradation rate of 0.5 percent and an annual utility rate escalation of 3 percent per year.

For the sites analyzed in this study that were served on SDG&E's small commercial "A" rate, we estimated LVOS for PV generation dedicated to offsetting common area load at about $0.22-$0.24 per kWh. We estimated LVOS for generation dedicated to offsetting tenant load at about $0.10 per kWh for the sites we analyzed where tenants were served on SDG&E's low income DR-LI tariff and received CARE discounts.

By our estimates, the levelized cost of energy (LCOE) for a PV retrofit is in the range of $0.06-$0.15 per kWh with the MASH incentive and $0.16-$0.25 per kWh without the MASH incentive if tax benefits are realized (Tables ES-1 and ES-2). LCOE is significantly higher without the tax benefits, at between $0.20-$0.31 per kWh with the MASH incentive and $0.32-$0.43 per kWh without the MASH incentive.

Thus, for properties with significant common area load, PV retrofits can be competitive with what would be paid for electricity on the common area meter — if tax benefits are utilized — even without the MASH incentive.[42] The lower value of tenants' avoided electricity payments makes projects designed primarily to offset tenant load economically challenging without MASH incentives.

Our investigation of the four study sites illustrates the better economic performance of PV retrofits at properties with significant common area loads. Of the four sites we evaluated in our study, two (Maryland and El Camino) have sizable common area loads (20,000-25,000 kWh/year) that are served on SDG&E's small commercial "A" tariff. Offsetting common area load at these sites would generate levelized electricity bill savings of about $0.22-$0.23 cents over the life of the PV system, within the range of the cost of a PV retrofit if tax savings can be utilized, even without the MASH incentive.

The other two sites (Georgia and Sycamore) had much smaller common area loads (1,500-4,500 kWh/year) that are served on SDG&E's residential "DR" tariff. The levelized bill savings from offsetting common area load at these sites is only about $0.15 per kWh. At all four of the sites we evaluated, tenants were served on SDG&E's low-income "DRLI" rate. The levelized bill savings from offsetting tenant use at these sites is about $0.10 per kWh.

The economic performance of a PV retrofit was best at the two sites at which offsetting common area load would generate significant bill savings. At the other two sites, the bill savings generated on the both the common area and tenant meters are lower than the cost of a PV retrofit, so PV at these sites is only economically viable with a MASH incentive.

6.2. Using VNM to Offset Tenant Load can be Economically Viable

In an affordable housing context, the higher electricity rates paid for common area consumption generally means that offsetting common area load will provide better economic performance than offsetting tenant load. However, if a property has significant common area load, the margin between the value of the utility bill savings on the common area load and the cost of energy can be high enough to allow the property

[42] The ITC Tax Credit for renewable energy technologies will expire in 2016. The MACRS accelerated depreciation tax benefit has been in place since 1986.

owner to offset lower-priced tenant load while still maintaining an economically viable project — even without the MASH incentive.

For example, in the case of one of the sites assessed in this study — the Maryland complex — the common area load would be offset by a 13 kW-DC system. At this system size, the levelized value of electricity savings is $0.22 and the LCOE is $0.17. The building, however, has available roof space for as large as a 33 kW-DC system. With virtual net metering, the property owner can make use of this extra roof space to offset tenant load. The PV system size can be expanded to 23 kW-DC and still break even, even without the MASH incentive. This assumes, however, that a portion of the electricity bill savings enjoyed by tenants can go to cost recovery for the PV system.

6.3. Cost-recovery from Tenants Significantly Improves Economics

PV retrofits can provide meaningful savings on tenant electricity bills. Our estimates of annual bill savings to tenants at one of the four sites examined (Georgia) is $250 per year if all the roof space available for PV is used. With the MASH incentives or other subsidies, property owners may be able to allow much of this savings to flow to tenants and still produce a positive economic return. However, without the MASH incentives — and in some cases, even with the incentives — the PV system owner would need to share in the tenants' bill savings to make PV retrofits that offset tenant load economically viable.

At two of the sites examined in this study (Georgia and Sycamore), PV retrofits designed to offset a significant portion of tenant load are only viable if a portion of the tenants' bill savings can be used to compensate the property owner for the cost of the PV system. At these sites, this is the case even if PV costs are reduced by the MASH incentive. At the other two sites (Maryland and El Camino), a significant portion of tenant load can be offset without any of the bill savings flowing to the property owner — but only if the MASH incentive is utilized.

If solar PV retrofits that offset tenant load are to be more widely deployed in the MF affordable housing sector without reliance on significant incentives, property owners will need to be able to recoup some of the PV investment costs by sharing in the tenants' utility bill savings. In our policy recommendations below, we describe possible mechanisms for making this cost recovery possible.

It is important to note that this study is focused on the project economics of property owners installing solar on affordable housing complexes. Noneconomic considerations may also enter into a property owner's decision-making when evaluating the costs and benefits of a PV system. An owner may want to do something positive for the environment and/or reduce his tenants' electric bills even if installing a system does not result in a positive economic return. This may be true particularly for nonprofit property owners for whom social concerns and tenant welfare may be the primary driver of decision making.

6.1. Utilizing Tax Benefits Dramatically Improves Economics

As is shown in Tables ES-1 and ES-2, system owners that can utilize PV's tax benefits will experience levelized costs of energy that are considerably lower than entities that are not able to take advantage of those benefits. For example — without the MASH incentive and assuming $7.2 per Watt-AC installation costs— we estimate the LCOE of a 30 kW-AC system at $0.17-$0.21 per kWh for a taxable entity versus

$0.34-$0.35 per kWh for a tax-exempt system owner. The utilization of tax benefits can bring project costs more in line with utility bill savings.

This finding is consistent with what CCSE has observed as a program administrator of the MASH Program, where we have seen a proliferation of MASH projects in which third-party financing structures are used such as power purchase agreements and solar leases that enable the utilization of tax benefits. According to a recent MASH program evaluation by Navigant Consulting, about three quarters of active MASH projects statewide are being pursued through 3rd party providers, in part because over half of active program participants are tax-exempt property owners.[43] The investment tax credit associated with PV is scheduled to expire in 2016. The ability of 3rd party providers to utilize tax benefits and provide other efficiencies to affordable housing property owners means that these providers are likely to play an important role in PV development in the affordable housing sector for years to come.

[43] Ibid. Pages 88 and 91

7. Policy Recommendations

Based on the findings from this study, we have outlined three policy/regulatory recommendations that if implemented could expand the solar PV market in the affordable housing sector and beyond:

1. As the MASH program moves forward, incentives should be reevaluated to ensure that they appropriately address the economics of offsetting tenant load versus common area load and of taxable versus tax-exempt system ownership
2. A standardized, simple mechanism should be developed that would enable property owners to share in some of the electricity bill savings provided to affordable housing tenants through PV retrofits
3. The virtual net metering tariff provides significant value to the affordable housing sector by enabling property owners to offset tenant load in an economically viable manner. Consideration should be given to expanding VNM beyond the affordable housing sector to other building types with large tenant loads and nonpermanent tenancy

7.1. Ensure that MASH program provides appropriate incentives for common area versus tenant loads

In its recent decision, the CPUC lowered the MASH incentive rate to $2.80/Watt-AC for capacity that offsets tenant load and $2.30 for capacity that offsets common area load.[44] Based on our findings in this study, it appears that PV retrofits can be cost-competitive with commercial or higher tier residential electricity rates in properties with significant common area usage. As is outlined above in Finding 1, when tax benefits are realized, we estimate the cost of PV retrofits to be in the range of $0.16-$0.25 per kWh without the MASH incentive. This is within striking range of the bill savings that PV would generate on common area meters with significant usage.

Low-income residential tenants, on the other hand, pay considerably less for electricity at about $0.08-$0.15 per kWh in the CA IOU territories. At the properties examined in this study, the levelized value of bill savings for tenants was about $0.10 per kWh, well below the cost of a PV retrofit even when tax benefits are realized.

As the MASH Program moves forward, careful consideration should be given to ensure that incentives are not unnecessarily high for projects designed to offset common area load, and are adequate for offsetting tenant load. The level of incentive that will enable property owner to offset tenant load will be in part be determined by the degree to which the property owner can recoup the costs of the PV investment by sharing in the utility bill savings enjoyed by the tenants. This issue is explored further in the next policy recommendation 2.

7.2. Develop Mechanism for PV Cost Recovery from Tenants

[44] CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Page 51.

Virtual net metering (VNM) enables affordable housing property owners to spread the benefits associated with a PV system among their tenants. It can be challenging, however, for property owners to collect revenue from their tenants in exchange for providing solar generation credits. Without a large cash incentive, like that provided through the MASH Program, and in some cases even with the incentive, a property owner would have to derive some cash flow from the reduced electricity costs that the tenants experience in order for a PV retrofit to be economically feasible. Generating this cash flow will only be viable if transaction costs can be kept low due to the low electricity bills paid by affordable housing residents and the correspondingly limited amount of revenue that a property owner would get from a given tenant.

We propose a mechanism that could enable property owners to recover costs associated with a PV investment in a way that would keep transaction costs relatively low. A standardized method could be developed that would adjust utility allowances in affordable housing to reflect tenants' lower electric bills post PV installation. In the case of publicly-owned housing, the utility allowance adjustment would have to be accompanied by an allowed rent increase to the property owner. In the case of Section 8 properties, the housing assistance payments that property owners receive would have to be adjusted to reflect reduced electricity costs to tenants. *The goal would be to reduce overall housing costs to tenants (rent+utilities), but create some mechanism for property owners to recover the PV system costs.*

7.2.1. Adjusting Utility Allowances and Rents in Publicly-owned Housing

In most affordable housing, rents are determined using a monthly utility allowance. Property owners could derive some cash flow from the reduced utility costs they provide to tenants though solar PV by adjusting the utility allowances for a particular complex. This would then allow the property owner to increase rents while keeping overall housing costs lower for tenants.

For affordable housing units, by Federal Housing and Urban Development (HUD) regulations, tenant rents are capped at 30 percent of a household's annual income. This "gross rent" includes both the payment for the unit rental and any costs associated with living at the complex that are not paid by the property owner, such as utility costs. A utility allowance (UA) is applied to a given unit type to compensate the tenant for reasonable utility costs (electricity, gas, sewer and water) such that the tenant's contribution to the gross rent (rent plus utilities) does not exceed 30 percent of the tenant's income.

Let's take for example the Maryland complex examined in this study, in which the units are all one-bedroom apartments designated for households that make no more than 50 percent of the area median income (AMI). Fifty percent of AMI in San Diego is about $27,500 for a single person. So the gross monthly rent for the unit would be capped at (0.3*$27,500)/12 = $688. The utility allowance in the Maryland complex is $26 per month for electricity and gas (the property owner pays water and sewer).[45] In this case, the tenant would pay $688-$26 = $662 in rent to the property owner. Let's say that after installation of a solar PV system, the tenant's electric bill is reduced on average by $15 per month. Perhaps $5 of that could go into the tenant's pocket and $10 could go to the property owner to cover the cost of the solar system. The utility allowance would then be adjusted to $16 per month. The rent paid to the property owner would increase by $10 per month, but the tenant's overall housing costs would be reduced by $5 per month or $60 per year. With 24 units, the property owner would receive an increased cash flow of $2,880 per year. This cash flow could go toward paying off the costs of the PV system.

[45] Based on June 2010 San Diego Housing Commission Utility Allowance Schedule

Property owners have some flexibility in how, and how often, they adjust utility allowances. HUD guidelines offer a number of methods to set UAs, and there is significant variation among local jurisdictions in how utility allowances are set. Property owners may hire external contractors to set UAs using HUD approved methods and software. These energy audits can be costly and burdensome, so some local housing authorities have attempted to standardize UAs and publish yearly tables that property owners can reference. For example, in June 2010, the San Diego Housing Commission instated a streamlined process for determining utility allowances based on the number of bedrooms in a given unit and the particular heating fuels and appliances used in the unit.

Over the past several years, efforts have been made to have local housing authorities approve UA adjustments to account for a property owner's investment in energy efficiency and solar. These efforts proved relatively unsuccessful. In order to obviate the need to get approval from each housing authority, the California Energy Commission and the California Tax Credit Allocation Committee (TCAC) created the California Utility Allowance Calculator (CUAC) in 2009. This free software module allows developers of new construction projects to better estimate the impacts of energy efficiency measures and solar PV on tenants' utility costs. Thanks to flexibility in IRS guidelines, property owners can bypass approval by the local public housing authority by using the CUAC calculator.[46]

The CUAC calculator, however, is only applicable to new construction and incorporates energy efficiency measures as well as the solar PV included in a given development. For *existing* structures that are adding a solar PV system, there needs to be a comparable calculator that allows property owners to adjust utility allowances to account for solar PV production. The calculator could build off existing PV production calculators and make conservative assumptions about PV production and electricity rates to ensure that tenants' UAs are not reduced unfairly.

It is important to note here that allowing for utility allowance adjustment does not necessarily mean that property owners can collect more rent. Additional changes to public housing assistance regulations may have to be made to enable property owners to recover costs from a PV retrofit through rent adjustments.

7.2.2. Recouping Cost in Section 8 Properties

For affordable housing property owners that receive income through the Section 8 rental assistance voucher program, simply adjusting utility allowances and rents does not appear to be a viable way to increase cash flow to the property owner. In these types of properties, the property owner receives two sources of income, the rent from the tenants and a "Housing Assistance Payment" (HAP) from the local housing authority.

The rent to the property owner provided by a given tenant is the gross rent less the utility allowance. The property owner receives compensation from the local housing authority or HUD for the difference between the rent he receives from the tenant and the constricted rent of the unit that is determined using HUD guidelines. In these cases, reducing the utility allowance would not increase cash flow to the property owner. The HAP paid to the property owner would decrease by the change in the utility allowance, resulting in no increased cash flow to the property owner.

For Section 8 rental assistance properties, one way to enable property owners to derive some cash flow from the solar generation credits the owner is providing to his tenants would be to hold the HAP payment

[46] Available at: www.gosolarcalifornia.org/affordable/cuac/index.php

constant despite the increased rent the property owner is receiving from the tenants. This would provide a positive cash flow to the property owner and could be justified by the following reasoning: The "fair market value" or constricted rent applicable to the property should be slightly higher for a property that enjoys the benefits of solar energy and the reduced electricity bills that the PV provides. The housing payment would have to be kept constant despite increased rent paid by the tenant (defined by the UA adjustment) in order to increase cash flow to the property owner. As described above, a streamlined process for adjusting utility allowances and allowing HAP payments to remain constant should be made available to property owners in order to reduce transaction costs of deriving cash flow for PV cost recovery from tenants.

7.2.3. Ensuring that low-energy users aren't penalized

From any given tenant's perspective, readjusting utility allowances to account for solar credits results in a positive cash flow only if the tenant's electric bill is at or above the amount of the solar credit. Table 20 shows the distribution of actual bills paid by tenants in the Maryland complex for 11 of 24 units for which we were able to collect data. The most recent utility allowance for these units is $26.18 per month.

Table 22. Tenant monthly electricity bills at Maryland

Monthly Bill	
Average	$17.09
Maximum	$28.61
Minimum	$7.84
Standard Deviation	$6.90
Data Points (N)	11

The data indicates the majority of tenants' electric bills are well below the UA defined for the property. Even if someone is paying less than the UA, as long as the solar credit that is attributed to their electric bill is less than their monthly bill, they will not lose money with a readjustment of the utility allowance. If, however, someone is only paying $10 a month for electricity, then receives a $15 solar credit per month, and sees their UA decreased by $15, they would lose $5 a month in cash flow.

When sizing PV systems and establishing the percent of the solar net metering credit to allocate to tenants, property owners should be mindful of ensuring that the monetary value of the solar credit will not be significantly higher than the electric bills of low electricity users.

7.3. Expand VNM beyond Affordable Housing

According to our modeling, PV retrofits can be cost competitive with more expensive commercial utility rates and higher tiered residential rates in California's three major investor-owned utilities when tax benefits are fully utilized, even without cash incentives. Without virtual net metering (VNM) in a multi-tenant setting, the additional costs and complexity of installing a separate system behind each tenant meter can create a barrier to PV investment. Expanding virtual net metering access to market-rate multifamily housing and non-residential tenant-occupied building segments would improve PV project economics in a significant portion of California's building stock.

PV project economics with VNM are likely to be more favorable in market-rate housing as compared to affordable housing, due to the higher electricity prices paid by tenants. In affordable housing, tenant electric bills are generally lower than in market-rate multifamily housing, as tenants tend to use less electricity and are on special discounted tariffs for low-income households. The monetary value of offsetting tenant electricity through virtual net metering in market-rate housing is thus likely to be greater than in an affordable housing context. Furthermore, property owners have fewer restrictions on adjusting rent in market-rate housing, so it is likely to be easier for property owners to create mechanisms for recovering PV costs from tenants. The same holds true for commercial multitenant buildings, such as shopping malls, office parks, etc. Given that VNM would improve PV project economics in market-rate multifamily housing and other tenant-occupied segments of the building stock, expanding access to VNM tariffs beyond affordable housing could significantly extend the market for distributed solar PV.

In July 2011, the California Public Utilities Commission (CPUC) recognized the value of VNM tariffs to other multi-tenant segments of California's building stock and directed CA's three largest IOUs to expand access to virtual net metering tariffs to all residential, commercial, and industrial multi-tenant and multi-meter properties.[47]

[47] CPUC Decision 11-07-031 per proceeding R.10-05-004 'California Solar Initiative Phase One Modifications' issued July 20, 2011. Pages 16-17.

References

Abramowitz, David (2008) Green Affordable Housing: Within Our Reach. *Center for American Progress.* www.americanprogress.org/issues/2008/12/green_housing_report.html

Barbose, G., Darghouth, N., and Wiser, R. (2010) Tracking the Sun III: The Installed Cost of Photovoltaics from 1998-2009. *Lawrence Berkeley National Laboratory LBNL-4121E* eetd.lbl.gov/ea/emp/re-pubs.html

Bolinger, Mark (2009) Financing Non-Residential Photovoltaic Projects: Options and Implications *Lawrence Berkeley National Laboratory LBNL-1410E* eetd.lbl.gov/ea/emp/re-pubs.html

Breidenbach, M., Mueller, G., Schulte, K.W.(2006) Determining Real Estate Betas for Markets and Property Types to Set Better Investment Hurdle Rates. *Journal of Real Estate Portfolio Management Volume 12, No.1*

California Solar Initiative Program Database. Available at California Solar Statistics www.californiasolarstatistics.ca.gov

Darghouth, N., Barbose, G., Wiser, R. (2010) The Impact of Rate Design and New Metering on the Bill Savings from Distributed PV for Residential Customers in California. *Lawrence Berkeley National Laboratory LBNL-3267E* eetd.lbl.gov/ea/emp/re-pubs.html

E3 Energy, Environment, and Economics. (2010) California Solar Initiative Cost-Effectiveness Evaluation. Individual Installation Draft Pro-Forma Tool Aug. 4, 2010. www.ethree.com/public_projects/cpuc.html

E3 Energy, Environment, and Economics. (2011) California Solar Initiative Cost-Effectiveness Evaluation. ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/csi/CSI%20Report_Complete_E3_Final.pdf

Global Green. Solar Affordable Housing Investment Calculator. www.globalgreen.org/solarcalculator

Mills, A., Wiser, R., Barbose, G. and Golove, W. (2008) The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California. *Energy Policy Volume 36(9) 3266-3277*

Navigant Consulting Inc. (2011) California Solar Initiative – Low Income Solar Program Evaluation. Market Assessment Report.

Itron, Inc. and Kema, Inc. (2010) CPUC California Solar Initiative 2009 Impact Evaluation. www.cpuc.ca.gov/NR/rdonlyres/70B3F447-ADF5-48D3-8DF0-5DCE0E9DD09E/0/2009_CSI_Impact_Report.pdf

Itron, Inc.(2011) CPUC California Solar Initiative 2010 Impact Evaluation.

US Department of Energy, Energy Efficiency and Renewable Energy Technologies Lab (2010). 2008 Solar Market Technologies Report. www1.eere.energy.gov/solar/pdfs/46025.pdf

US Department of Housing and Urban Development. Housing Choice Vouchers Fact Sheet. www.hud.gov/offices/pih/programs/hcv/about/fact_sheet.cfm. Sep 17, 2010

Wiser, R., Mills, A., Barbose, G. and Golove, W. (2007) The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California. *Lawrence Berkeley National Laboratory LBNL-63019* eetd.lbl.gov/ea/emp/re-pubs.html

Appendices

Appendix A. Measures of Economic Performance

We used several measures of financial/economic performance to evaluate the relationship between virtual net metering and PV project economics. Each metric has its particular applications and advantages and disadvantages. Taken together, the metrics give a more complete sense of a project's cost-effectiveness.

Levelized Cost of Energy (LCOE)

We used the levelized cost of energy (LCOE) to evaluate the cost of producing PV electricity on a per unit of energy basis. The LCOE is the present value of the costs of energy production, including O&M costs, divided by the total energy produced during the product's useful life. This gives a price per unit of energy, generally represented in dollars or cents per kWh.

The LCOE is defined by the equation:

$$LCOE = \frac{\text{Present Value of Total System Life Cycle Costs}}{\text{Present Value of Total Lifetime System Energy Production}}$$

Because tax impacts significantly affect the cost of renewable energy, we estimated the **after tax LCOE** in our modeling. The tax impacts of owning PV vary considerably by sector. We defined the LCOE in a manner that reflects the costs experienced by the system owner, with any rebates and tax benefits accounted for.

This is represented by the following equation:

$$LCOE = \frac{\text{Inst Cost} - \text{Reb} \;+\; \dfrac{\sum_{t=1}^{T} \text{Tax Cred} + \sum_{t=1}^{T} O\&M * (1-\tau) + \sum_{t=1}^{T} \text{Dep} * \tau}{(1+r)^{t}}}{\dfrac{\sum_{t-1}^{T} \text{Initial kWh} * (1-d)^{t}}{(1+r)^{t}}}$$

Where:

Inst Cost	=	Total Installed Cost
Reb	=	Any Cash Incentives Received
Tax Credit	=	The ITC tax credit (which we assumed would be realized at the end of yr 1 but can be spread over as much as 5 years)
O&M	=	Annual Operations and Maintenance Costs
Dep	=	Depreciation
Initial kWh	=	The First-Year System Performance
T	=	Life Span of the System in Years
t	=	Given Year
d	=	System Performance Degradation
τ	=	Tax Rate
r	=	Discount Rate

The LCOE is a useful metric for evaluating the cost of producing energy across various technologies, sizes, time scales and financing structures. The LCOE can be compared to per kWh costs of alternative technologies and to grid-supplied electricity to evaluate the cost-effectiveness of a DER project.

Levelized Value of Bill Savings (LVOS)

When modeling cash flows for a distributed energy resource (DER) that is displacing grid-supplied energy, the major source of cash inflow to the host customer is the savings generated by the DER. That is, the purchases of energy from the utility that the DER host customer no longer has to make thanks to the on-site energy generated.

This metric is dependent on the particular utility service territory in which the customer is located and the tariff schedule the customer is on. Tariff schedules usually vary by the customer's sector — commercial, industrial, residential — as well as the level of the customers' peak energy demand (kW).

Over the life of the PV system, the total avoided electricity purchases can be levelized on a per kWh basis to give a sense of what the host customer would have had to pay had he not invested in a PV system. We have termed this the "levelized value of bill savings" (LVOS), the present value of the avoided electricity purchases per kWh of energy generated by the PV system.

The LVOS can then be compared to the LCOE of the PV system. If the LVOS is greater than the LCOE, then the project will result in electricity cost savings compared to purchasing grid-supplied energy. The LVOS can also be used as a benchmark to compare to the energy price offered through a power purchase agreement (PPA).

The LVOS is defined by the equation:

$$LVOS = \frac{\text{Present Value of Total Avoided Costs}}{\text{Present Value of Total Lifetime System Energy Production}}$$

This is represented by the following equation:

$$LVOS = \frac{\frac{\sum_{t=1}^{T} (\text{Year 1 Electricity Savings} * (1+\varepsilon)^t * (1-d)^t)}{(1+r)^t}}{\frac{\sum_{t-1}^{T} \text{Initial kWh} * (1-d)^t}{(1+r)^t}}$$

Where:

Initial kWh	=	The First-Year System Performance
T	=	Life Span of the System in Years
t	=	Given Year

d	=	System Performance Degradation
r	=	Discount Rate
ε	=	Estimated annual utility rate escalation (%)

Net Present Value

The LCOE and the LVOS provide a sense of the costs and benefits of a project per kWh of consumption and production. These metrics do not, however, provide a measure of the overall cost-effectiveness of a DER investment. The net present value (NPV) is a commonly used metric to evaluate the cost-effectiveness of an investment. To establish the NPV of an investment, all cash inflows and outflows are estimated over the life of the investment, tax impacts are accounted for and all net cash flows are discounted to present value. The sum of all discounted net cash flows is the NPV of the investment.

NPV is represented by the formula:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} - I_0$$

CF	=	Annual Net Cash Flow
T	=	Life Span of the System in Years
t	=	Given Year
r	=	Discount Rate
I	=	Initial Investment

If NPV is greater than zero, the investment will be profitable. The NPV as an overall dollar amount also gives the investor a sense of the scale of profitability. The NPV is sensitive to the discount rate used to discount cash flows to present value. The discount rate is the rate of return that an investor would expect to achieve were he to invest in an alternative investment of comparable risk. The discount rate should account for the opportunity cost of what the investor could be gaining from a given amount of money were he to use his money on something other than, in this case, a solar PV project. If investors are not sure what their discount rate is, they may either want to evaluate NPV at various discount rates or use other metrics, such as a project's internal rate of return (IRR) to evaluate the profitability of an investment.

Appendix C. Additional Model Assumptions

Discount Rate

When valuing future cash flows, it is critical to account for the time value of money. This is done by discounting future cash flows by a discount rate that is usually represented as a percentage. The discount rate should capture the investor's opportunity cost of what could be earned by investing in alternative investments of equivalent risk. This discount rate, or "hurdle rate," is a critical component of valuing cash flows over the life of the system.

Establishing a hurdle rate for investments in affordable housing is challenging. Affordable housing projects often have multiple funding sources, diverse risks and benefits associated with projects and may find it difficult to establish an expected return from alternative investments.

We decided to use a discount rate that would be reasonable for private apartment real estate investments. One strategy is to survey investors and establish an average hurdle rate. However, obtaining data from a large enough sample size of investors was beyond the scope of our work. Additionally, investors may be biased by current conditions and may not provide the best measure of a hurdle rate for a long-term 25-year investment.

We chose to use the capital asset pricing model (CAPM) approach to establish a discount rate for a private-sector property owner or investor. The CAPM model adds a market risk premium to the return on a "safe" investment, such as a U.S. Treasury Bond, to calculate a hurdle rate for a given investment. This market risk premium is adjusted by a "beta" that captures the particular risk of the type of asset being analyzed. While CAPM has certain drawbacks, it is a commonly used method in financial valuation and has proven to be relatively robust.

The CAPM model can be summarized by the equation:

$$r = r_f + \beta(r_m - r_f)$$

Where:

r = Discount Rate
r_f = the risk free rate of return
r_m = the expected market rate of return
β = a measure of the risk associated with the asset

Breidenbach et al. (2006) used returns from publicly traded real estate investment trusts (REITs) to estimate critical components of the CAPM for various real estate sectors. During 1979-2000, they estimated a market risk premium of 6.4 percent for real estate assets based on the NAREIT Equity Index. For the apartment sector, they estimated a beta of 0.72.

Using the CAPM for our modeling and Breidenbach et al.'s findings reasonably reflect the long-term cost of capital for real estate investments. We used the White House Office of Management and Budget's 2010 25-year T-bill return estimate as our risk free rate. So by CAPM, the hurdle rate for a private sector investor is:

$$r = 5\% + .71(6.4\%) = 8.2\% \text{ or approximately } 8\%$$

Therefore we used a discount rate of eight percent, assuming a property owner operates in the private sector. For the government and nonprofit sectors, we used the risk free rate of five percent as the discount rate.

Residual Value

Because there is limited information on either salvage value or disposal costs on 25-year PV systems, we assumed no residual value at the end of the system life.

Renewable Energy Credits

A benefit that can accrue to a property owner through investment in a PV system is renewable energy credits (RECs). When a PV system owner sells the RECs associated with a PV project, they are selling the green attributes associated with the project. We assumed that property owners would want to be able to retain the green attributes associated with PV systems and thus did not include any REC revenue in our calculations.