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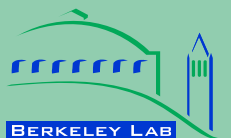
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The Economic Value of PV and Net Metering to Residential Customers in California

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THE ECONOMIC VALUE OF PV AND NET METERING TO RESIDENTIAL CUSTOMERS IN CALIFORNIA

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ABSTRACT

In this paper, we analyze the bill savings from PV for residential customers of the California's two largest electric utilities, under existing net metering tariffs as well as under several alternative compensation mechanisms. We find that economic value of PV to the customer is dependent on the structure of the underlying retail electricity rate and can vary quite significantly from one customer to another. In addition, we find that the value of the bill savings from PV generally declines with PV penetration level, as increased PV generation tends to offset lower-priced usage. Customers in our sample from both utilities are significantly better off with net metering than with a feed-in tariff where all PV generation is compensated at long-run avoided generation supply costs. Other compensation schemes which allow customers to displace their consumption with PV generation within each hour or each month, and are also based on the avoided costs, yield similar value to the customer as net metering.

1. INTRODUCTION

Net metering has become a widespread policy in the U.S. for supporting distributed photovoltaics (PV) adoption. Though specific design details vary, net metering allows customers with PV to reduce their electric bills by offsetting their consumption with PV generation, independent of the timing of the generation relative to consumption – in effect, compensating the PV generation at retail electricity rates (Rose et al. 2009).

While net metering has played an important role in jump-starting the residential PV market in the U.S., challenges to net metering policies have emerged in a number of states and contexts, and alternative compensation methods are under consideration. Moreover, one inherent feature of net metering is that the economic value it provides to customers with PV depends heavily on the structure of the underlying retail electricity rate, as well as on the characteristics of the customer and PV system. Consequently, the value of net metering – and the impact of moving to alternative compensation mechanisms – can vary substantially from one customer to the next. For these reasons, it is important for solar stakeholders to understand both how the value of PV varies under net metering, and how the value of net metering compares to other possible compensation mechanisms.

To advance this understanding, we analyze the bill savings from PV for *residential* customers of the California's two largest electric utilities, Pacific Gas and Electric (PG&E) and Southern California Edison (SCE), based on actual hourly load data and simulated hourly PV production. We first compute the bill savings based on existing net metering rules and retail electricity rates, and then compare the value of the bill savings under net metering to three potential alternative compensation mechanisms, each of which provides bill credits for some or all PV production at prices based on the state's Market Price Referent (MPR).¹

¹ The MPR is the price used by the utilities and the California Public Utility Commission to evaluate wholesale contracts with renewable generators and is intended to represent long-run avoided generation supply costs, based on the cost of a combined-cycle natural gas fired generator.

Prior studies have investigated aspects of the customer economics of PV under net metering and the relationship to retail rate structures. Hoff and Margolis (2004) and Borenstein (2008) show that net-metered time-of-use rates can increase the value of PV generation. Borenstein (2007) investigates whether the requirement (since repealed) that customers receiving incentives under the California Solar Initiative take service on a TOU rate eroded customers bill savings and caused a decline in PV demand in California. The present paper uses the same customer load data and expands upon the analysis presented in Borenstein (2007), in which he evaluates the impact of TOU rates on PV value in California. MRW and Associates (2007) evaluated which retail rate structures provide the greatest benefits to different classes of PV customers in California. Mills et al. (2007) investigate the impact of retail rate structure on the value of PV for commercial customers in California, focusing in part on the extent to which PV can reduce customer demand charges. The present study updates and expands upon this prior work by investigating additional factors that affect the value of PV for residential customers and the value of net metering relative to potential alternatives.

2. DATA

Our analysis relies on 15-minute interval load data from residential customers located throughout the service territories of PG&E and SCE, none of which have PV systems installed. These data were originally collected for California's Statewide Pricing Pilot (see Charles River Associates, 2005, for more details). Our analysis utilizes data for the Statewide Pricing Pilot (SPP) control group of customers, who were not under peak pricing rate structures. The original SPP control group dataset consisted of load data from 442 customers. Following data cleaning, which consisted of removing incomplete data and customers in multi-family housing, load data from 215 customers (118 PG&E customers and 97 SCE customers) were ultimately used in our analysis. Though the original dataset included some San Diego Gas and Electric (SDG&E) customers, data from these customers were excluded from our analysis due to inadequate sample size.

PG&E customers in our sample had usage of 667 kWh/month in the median case, and 734 kWh/month on average. In comparison, SCE customers in our sample are slightly larger, with usage of 730 kWh/month in the median case and 827 kWh/month on average. Customers in our final sample are, on average, larger than the overall population of residential customers (by 30% and 38% for PG&E and SCE, respectively). This is, at least in part, a consequence of the fact that removed customers in multi-family residential buildings (e.g., apartments) from our

sample, who on average have lower electricity consumption than customers in single-family homes.

Each customer within our load data sample was matched with simulated PV production data. For our analysis, we used PV simulation data from the National Renewable Energy Laboratory (NREL), based on the PVFORM/PVWatts Model and the National Solar Radiation Database (NREL 2007, Denholm et al. 2009, NREL 2010). The data consists of simulated hourly AC electricity generation for a 1 kW system located at each of 73 weather stations located throughout California, derived from weather data for the same 12-month period as the customer load data (October 1, 2003 through September 30, 2004). The tilt used for our default case is 25° South (azimuth=180°); this azimuth produces the most kWh per kW in the northern hemisphere, and 25° is a typical angle for a sloping rooftop. We also conducted sensitivity analyses for two alternate PV panel orientations: a 240° azimuth (approximately west-southwest, though we refer to this orientation from here on simply as "southwest") with a 25° tilt, and flat-mounted system (i.e., tilt=0°). The southwest orientation was chosen, because systems facing this direction receive more sunlight during the on-peak TOU period when retail electricity rates are highest under the utilities' TOU rates. The no-tilt orientation was chosen to represent systems installed on flat roofs, which are common in some parts of California. Each customer within the load data set was assigned to the PV production data from the nearest of the 73 weather stations.

For each paired set of customer load and PV production data, the simulated hourly PV production was scaled so that total annual PV generation would equal specific percentages (herein referred to as "PV penetration levels") of the customer's annual consumption. Three PV particular PV penetration levels – 25%, 50%, and 75% – were used throughout our analysis. We did not include a 100% PV penetration case, as systems of this size would result in uncompensated bill credits at year-end for many customers, under current net metering rules.

3. RESIDENTIAL ELECTRICITY RATES

PG&E and SCE both offer residential customers the choice between a non-time-differentiated (i.e., "flat") rate and a time-of-use (TOU) rate. The utilities' flat rates are "inclining block" rates with five usage tiers and increasing volumetric charges for usage within each successive tier. The lowest tier is the baseline allotment, which varies according the baseline region in which the customer is located and is designed to cover 50-60% of the average electricity consumption in the region. The other four tiers are defined as percentages of the baseline: specifically, Tier

2 is 100-130% of the baseline, Tier 3 is 130-200%, Tier 4 is 200-300%, and Tier 5 is greater than 300%.

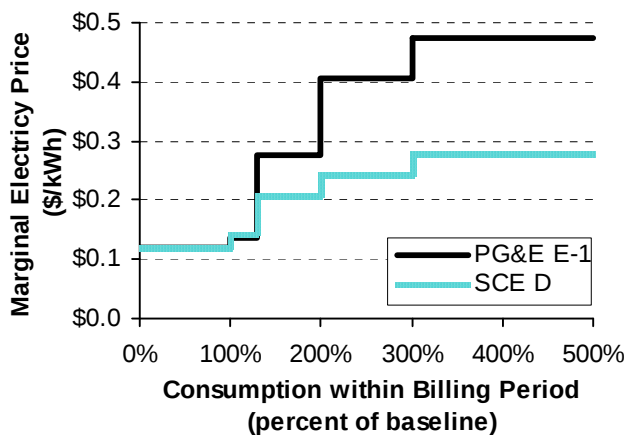


Fig. 1: Flat rates for PG&E and SCE residential customers

Error! Reference source not found. displays the tiered rate structure for PG&E's and SCE's flat rates, as of March 2010. As shown, prices for usage in the highest tiers of both utilities are considerably greater than in the baseline tier, but PG&E's tiers are significantly steeper than SCE's. Specifically, volumetric charges under PG&E's flat rate rise from \$0.12/kWh for usage in Tier 1 up to \$0.47/kWh in Tier 5, while SCE's rate rises from \$0.12/kWh for usage in Tier 1 up to \$0.28/kWh in Tier 5. Both utilities' flat rates also specify a minimum monthly charge, and SCE's flat rate also contains a fixed customer charge.

Under the utilities' residential TOU rates, volumetric charges vary according to both the season (summer vs. winter) and the time of day, with either two or three TOU periods during each day, depending on the utility and the season. Electricity consumed during TOU "peak" periods is higher priced than that during "part-peak" (when applicable), which is in turn more expensive than that consumed during the "off-peak" period. Electricity consumed in the summer season is more expensive than that of the winter season, and this difference is most significant for the on-peak periods. PG&E's residential TOU rate is tiered, with the same five usage tiers within each TOU period as are used on the utility's flat rate. Customers on the TOU rate are thus allocated a baseline allotment for each TOU period, and usage within each TOU period is charged according to the tier within which it falls. SCE's residential TOU rate is also tiered, though it only has two tier levels, with Tier 1 corresponding to consumption up to 130% of the baseline level and Tier 2 corresponding to all consumption over that level. As of February 2010, SCE's TOU rate is currently in the review stage, and is soon to be open to new customers.

4. UTILITY BILL SAVINGS CALCULATIONS

We calculated annual utility bills for each customer, both with and without a PV system, under each of the available residential retail rates offered by its utility. Utility bills with PV systems were calculated for each possible combination of:

- PV penetration rate (25%, 50%, and 75%);
- PV orientation (south-facing at a 25° tilt, southwest facing at a 25° tilt, and flat); and
- PV compensation mechanism (net metering, MPR-based feed-in tariff, hourly netting, and monthly netting).

All bill calculations are based on the retail rates, net metering rules (if applicable), and MPR prices (if applicable) in place as of February 2010. Further details on the bill calculation procedure for each PV compensation mechanism are as follows.

4.1. Net Metering

Utility bills within each month were calculated by first computing the net electricity consumption – that is, the difference between gross electricity consumption and PV electricity production – within each TOU period of each month. The total net consumption for the billing month (i.e., the sum of the net consumption over all TOU periods) was then compared to the customer's baseline allocation for that month to determine the quantity of consumption within each usage tier. Charges for net consumption within each usage tier were then calculated based on a weighted-average of the volumetric prices for each TOU period, where those prices were weighted according to the customer's net consumption within each TOU period.

If the monthly utility bill calculated according to the preceding procedure is less than the minimum monthly charge, this is applied as a bill credit. However, at the end of the 12-month analysis period, if a bill credit remains after all monthly bills are summed, it is forfeited by the customer.²

4.2. Alternative PV Compensation Mechanisms

Three hypothetical alternatives to net metering were considered. Under each alternative, some portion of the PV production is compensated at an MPR-based rate (rather

² California passed legislation (AB920) in October 2009 mandating that utilities provide net metered customers with the option of receiving compensation for any net generation at the end of the year. As of the writing of the present paper, new net metering tariffs had not yet been adopted to implement this requirement, and thus this revision to the state's net metering rules was not incorporated into our analysis.

than at the retail electricity rate, as is the case under net metering) and is credited against charges for the customer's usage. In each case, we use the approved 2009 baseload MPR rate for a 20-year contract with deliveries beginning in 2010, equal to \$0.09674/kWh. The baseload MPR is multiplied by approved Time-of-Delivery adjustment factors to determine the appropriate rate, depending on the time when the electricity is exported to the grid.

The three alternative PV compensation mechanisms and associated bill calculation procedures are as follows. Note that these do not necessarily represent existing options for PG&E and SCE customers.

- (1) *An MPR-based feed-in tariff*, under which the customer is credited for all PV generation at the MPR rate;
- (2) *Hourly netting*, whereby PV production can offset up to 100% of customer usage within each hour, but any excess hourly production is credited at the applicable MPR rate; and
- (3) *Monthly netting*, whereby PV production can offset up to 100% of customer usage within each TOU period of each month, but any excess monthly production is credited at an MPR-based rate.

4.3. PV Value Metric

To determine the value of the utility bill savings to each customer, we compare the annual utility bill with and without a PV system, for each combination of PV penetration level, PV orientation, and compensation mechanism. Unless otherwise noted, we assume that customers choose the least-cost rate before and after PV installation. We express the bill savings on a \$/kWh basis, in terms of the annual reduction in the utility bill per kWh generated by the PV system, as shown in equation (1):

$$PV\ Value = \frac{Bill_{noPV} - Bill_{PV}}{PV\ Generation} \quad (1)$$

Expressing PV value in terms of \$/kWh allows for a direct comparison of electricity bills between customers with different loads as well as between alternate PV penetration levels. Also, since electricity is charged to retail customers per kWh and the rate paid to generators (e.g. MPR rate) is also per unit energy output, the units and the significance of the numbers can easily be interpreted.

5. FINDINGS

In this section, we introduce the principal results of our research. Looking at the rates currently available to SCE

and PG&E customers, as of February 2010, we first determine which rates are least-cost for the customers in our sample. Assuming least-cost rate choice, we then present the value of PV under net metering, followed by a calculation of PV system size needed to exhaust annual bill savings. Next, we compare the value of PV with net metering with alternative electricity compensation schemes. We finally investigate the potential impact of a transmission and distribution (T&D) adder.

5.1. Least-Cost Rate Selection

Under net metering, the utilities' TOU rates become least-cost for an increasing percentage of customers as PV penetration level increases (see Figure 2). For customers of each utility, the least-cost rate choice is driven primarily by the peakiness of the rate options available. With no PV system installed, virtually none of the PG&E customers in our sample would minimize their bill under the TOU rate, while 46% of SCE customers would do so. This difference can largely be attributed to the fact that SCE's TOU rate has only one TOU period (the summer peak period) with prices higher than its flat rate, while PG&E's TOU rate has two TOU periods (the summer peak and summer part-peak periods) with prices higher than its flat rate. For both utilities, the percentage of customers for which the TOU rate is least-cost increases steadily with PV penetration, such that at a 75% PV penetration level, 83% of PG&E customers and 99% of SCE customers in the sample would find the TOU rate to be least cost.

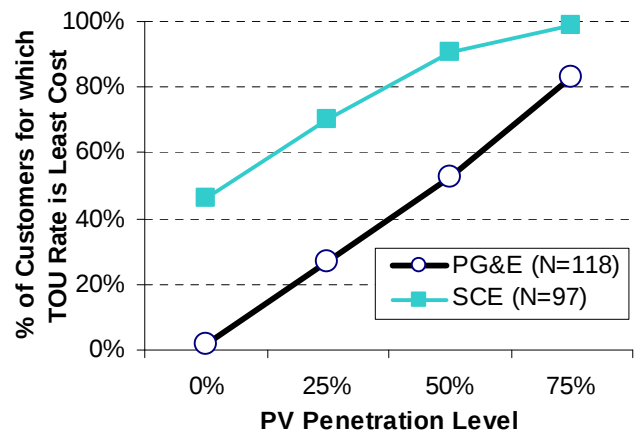


Fig. 2: Least-Cost Rate Choice at Varying PV Penetration Levels

5.2. Value of PV under net metering

Figures 3a and 3b, which present the value of PV for each customer at each of the three PV penetration levels for

PG&E and SCE, exhibit several basic trends. First, the value of PV varies significantly across customers, as a result of differences in customer usage level – where PV value is greatest for high-usage customers, who are able to offset consumption in high-priced usage tiers. For example, at a 50% PV penetration level, the value of PV for PG&E customers rises from a low of approximately \$0.11/kWh for customers in Tier 1 (<100% of baseline) to \$0.35-\$0.45/kWh for customers in Tier 5 (>300% of baseline). For SCE, the relationship is somewhat less pronounced, due to the fact that SCE’s usage tiers are considerably less-steep than PG&E’s. At a 50% PV penetration, the value of PV for SCE customers rises from a low of approximately \$0.11/kWh for customers in Tier 1 to approximately \$0.26/kWh for customers in Tier 5.

Second, the value of PV under net metering declines with PV penetration level. In the median case, the value of PV among the PG&E customers declines from \$0.24/kWh at a PV penetration level of 25% to \$0.19/kWh at a 75% penetration, while the median value for the SCE customers declines from \$0.21/kWh to \$0.18/kWh over this range of PV penetration. The decline in PV value with PV penetration, however, is much more pronounced for high-usage PG&E customers, with the value of PV for the top 10% of PG&E customers declining from \$0.42/kWh to \$0.32/kWh between 25% and 75% PV penetration levels.

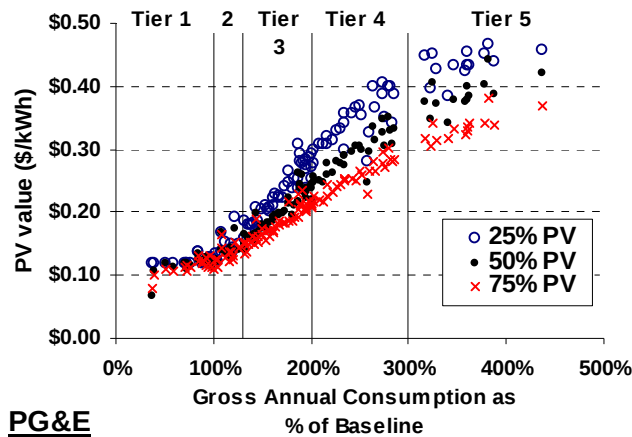


Fig. 3a: Variation of PV Value with Customer Gross Annual Consumption (PG&E)

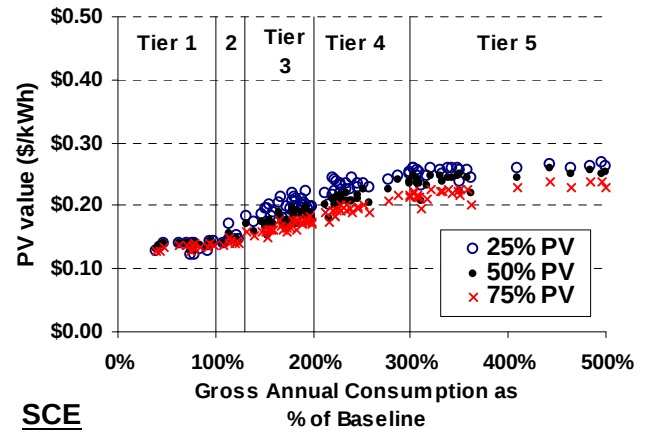


Fig. 3b: Variation of PV Value with Customer Gross Annual Consumption (SCE)

5.2.1. Impact of sub-optimal rate choice on PV value

For our base-case net metering analysis, we assume that customers choose the least-cost rate option, both before and after PV installation. However, we also examine a scenario under which customers make sub-optimal rate choices following installation of the PV system, and we compare the value of PV between this scenario and our base-case (see Figure 4). In general, the results show that the loss in value associated with improper rate selection is relatively modest. For PG&E customers, the median loss in bill savings ranges from about \$0.012-\$0.029/kWh across PV penetration levels, corresponding to a 6-11% loss in PV value. For SCE customers the median loss in bill savings ranges from about \$0.015-\$0.021 /kWh across PV penetration levels, an 8-10%

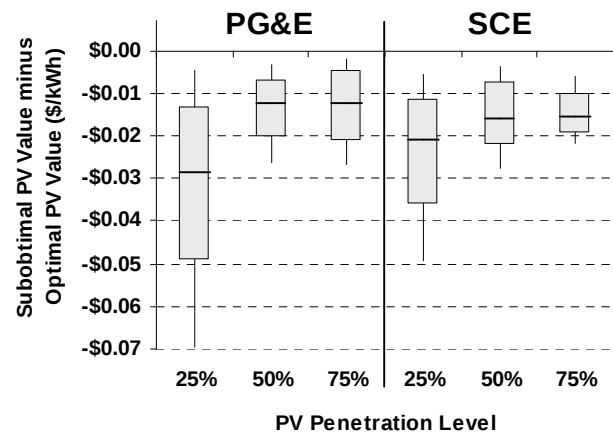


Fig. 4: Distribution in the Change in the Value of PV from Sub-Optimal Rate Selection. *Note:* Box plots identify 10th/25th/50th/75th/90th percentile values.

loss in PV value. At low PV penetrations, however, the loss in PV value associated with improper rate selection can be substantially greater for those customers with particularly flat or peaky load profiles.

5.2.2. Impact of PV panel orientation on PV value

For our base-case net metering analysis, we assume that PV panels face due-south at a 25° tilt. To test the effect of alternate PV orientations, we also calculated the value of the bill savings for systems at an azimuth of 240° (approximately west-southwest) with a 25° tilt, and for systems with no tilt (i.e. mounted flat on a non-sloping rooftop). In general, all comparisons show that the difference in PV value between alternate PV orientations is quite modest – in most cases, less than \$0.01/kWh.³

5.3. Maximum PV Size to Exhaust Annual Bill Savings

PG&E's and SCE's current net metering tariffs allow customers to offset all volumetric energy charges over the course of year, but any excess bill credits remaining at year-end are forfeited by the customer. As a result, net metered customers on TOU rates will typically exhaust their annual bill savings with PV systems sized to meet less than their total annual consumption. To quantify this effect, we calculated, for each customer, the PV penetration level that exhausts the annual bill savings under existing net metering rules (see Figure 5). Within our sample, 83% of PG&E customers and 81% of SCE customers would exhaust their bill savings with PV systems sized to meet less than 100% of their annual usage. In the median case, PG&E customers exhaust their bill savings at a PV penetration of 95%, and

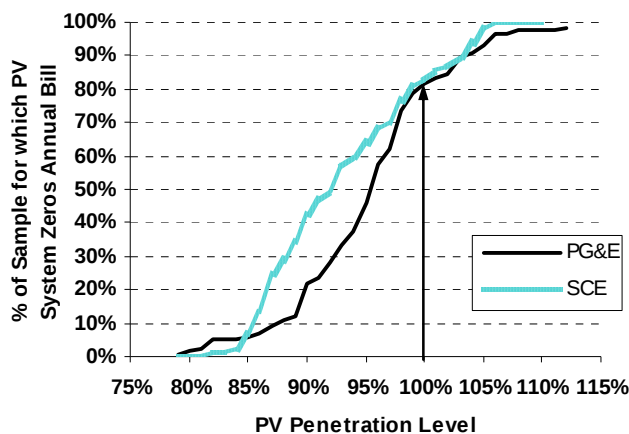


Fig. 5: PV System Size that Exhausts Annual Bill Savings

³ Though the value per kWh of electricity produced is not impacted significantly, the annual output per KW installed decreases by 11% and 10% with our alternative orientations, azimuth=240° & tilt=25° and no tilt, respectively.

SCE customers at a PV penetration of 92%. While this analysis is based on current net metering rules (as of February 2009), legislation enacted in California in 2009 (AB 920) requires that PG&E and SCE revise their net metering tariffs such that customers receive compensation for PV production in excess of their annual consumption.

5.4. Value of PV under Alternative PV Compensation Mechanisms

As explained in Section 4.2, the value of the bill savings from PV was calculated for each customer, under each of three alternatives to net metering: a full MPR-based feed-in tariff, hourly netting, and monthly netting. Figures 6a and 6b show the distribution in the difference between the value of PV under each of these alternatives compared to net metering. A negative value, therefore, indicates that the value of PV to the customer is lower under the alternative than under net metering.

Focusing first on the full MPR-based feed-in tariff, we see that the value of PV is substantially less than under net metering. This is particularly true for PG&E customers, where the median bill savings are \$0.12/kWh lower at a 25% PV penetration level and \$0.08/kWh lower at a 75% PV penetration (i.e., a loss in value of 52% and 39%, respectively, compared to net metering). However, the distribution is quite wide, with much greater erosion in PV value occurring for high-usage customers, who benefit most from net metering. Of the PG&E customers in our sample, one-quarter would experience a reduction in bill savings of more than \$0.22/kWh (65%) at 25% PV penetration and more than \$0.14/kWh (54%) at a 75% PV penetration. For SCE customers, the difference between the MPR-based feed-in tariff and net metering is less severe than for PG&E, but still sizable. In the median case, bill savings under the MPR-based feed-in tariff are \$0.08/kWh (39%) lower than under net metering at a 25% PV penetration level, and \$0.05/kWh (27%) lower at a 75% PV penetration. The absolute reduction in bill savings is less for SCE customers than for PG&E customers, in part because the value of PV under net metering is generally lower for SCE, and in part because SCE has a much higher summer peak period MPR adjustment factor (3.13, compared to 2.20 for PG&E), making MPR-based compensation for PV production more lucrative for SCE customers than for PG&E customers.

Turning to the other two alternative compensation mechanisms – hourly and monthly netting – we see that neither of these options would result in a substantial erosion of value to the customer, relative to net metering. Under hourly netting, customers of both utilities would generally experience a reduction in the value of PV relative to net metering, but the difference is significantly less than under the full MPR-based feed-in tariff. Specifically, the median

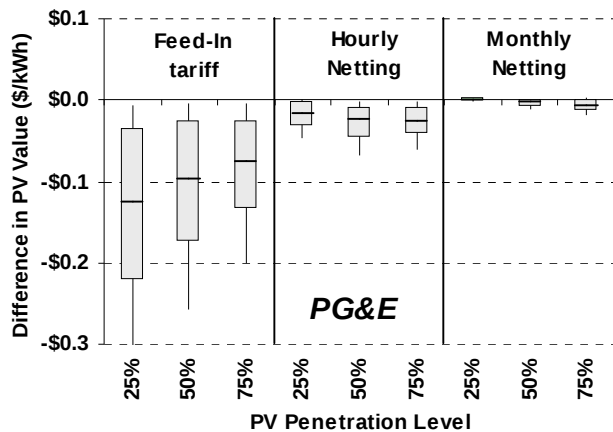


Fig. 6a: Difference in PV Value between Alternative PV Compensation Mechanisms and Net Metering (PG&E)

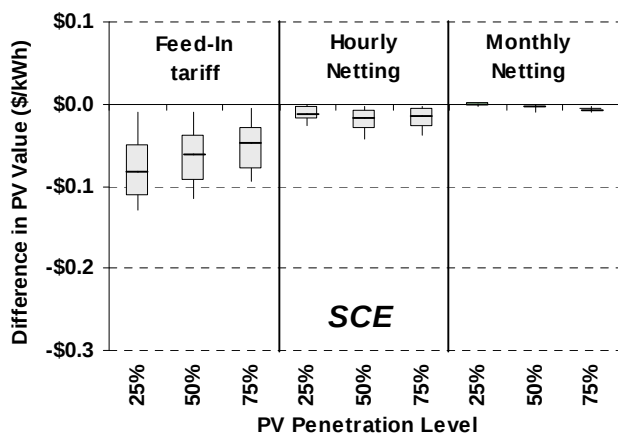


Fig. 6b: Difference in PV Value between Alternative PV Compensation Mechanisms and Net Metering (SCE)

loss in value ranges from \$0.02/kWh to \$0.03/kWh for PG&E customers, across the PV penetration levels examined, and from \$0.01/kWh to \$0.02/kWh for SCE customers. Under monthly netting the value of PV is negligibly lower than under net metering (i.e., a loss in PV value of less than \$0.01/kWh).

5.5. The Potential Impact of a T&D Adder

The alternative compensation mechanisms considered are based on the state's MPR, which represents avoided wholesale generation supply costs only. However, distributed PV could also potentially result in avoided transmission and distribution (T&D) capacity costs and reduced T&D line losses, which could conceivably be incorporated into an avoided cost-based feed-in tariff. We did not attempt to incorporate these factors into the alternative compensation mechanisms considered. However, other studies that have estimated avoided T&D

costs from distributed PV generally suggests that accounting for these avoided costs would have only a marginal impact on our overall results. Although exceptions exist, most studies that have attempted to quantify average avoided T&D *capacity costs* from distributed PV have derived estimates in the range of \$0.001-\$0.01/kWh (Hoff *et al.*, 2006; Kahn, 2008; R.W. Beck, 2009; Simons, 2005). Incorporating an adder of this magnitude into the alternative compensation mechanisms modeled in our analysis would not materially alter the results. In addition, Energy and Environmental Economics (2004) estimated the value of reduced T&D line losses for PG&E and SCE to be in the range of \$0.01-\$0.02/kWh, which also would have only a modest impact on the value of the alternative compensation mechanisms. It is important to acknowledge, however, that avoided T&D capacity costs are highly idiosyncratic – depending on the particular size, timing, and location of an individual PV system – thus there are circumstances where avoided T&D capacity costs from distributed PV could be much more significant than the average values cited above.

6. CONCLUSIONS

Net metering, in combination with other policy support mechanisms, has been instrumental in jump-starting the market for distributed PV in California and elsewhere in the U.S. An inherent feature of net metering is that the economic value that distributed PV provides to the customer is highly dependent on the underlying retail rate structure. In the case of PG&E and SCE, the residential electricity rates have inclining usage tiers that are quite steep compared to inclining block rates implemented elsewhere in the U.S. As a result, the value of PV under net metering varies widely across PG&E and SCE customers (i.e., by a factor of 4-5 for PG&E and by a factor 2-3 for SCE), depending on the customer's usage level and the relative size of the PV system.

In the early stages of market development, this variation may serve a useful purpose by providing high levels of compensation for a sub-set of customers and thereby fostering early adoption. In the long-run, however, this variation in the value of PV could be problematic if, for example, it introduces a high level of complexity and uncertainty for customers considering a potential investment in distributed PV.⁴

One potential alternative is to simply compensate all distributed PV electricity production under a feed-in tariff. Our analysis indicates that, if the price of the feed-in tariff

⁴ Moreover, retail rate structures are subject to change over the life of a PV system, introducing further uncertainty for a customer considering a PV installation.

were set at the avoided wholesale electricity generation cost in California, the value of PV would be significantly eroded for most PG&E and SCE customers. Increasing the feed-in tariff price to account for average avoided T&D costs and losses would only marginally reduce the erosion in PV value for most customers.

Alternatively, an argument could be made that PV installed on the customer-side of the meter should not be treated fundamentally different from energy efficiency upgrades installed by the customer, and that therefore distributed PV production should be able to offset up to 100% of customer usage, but any excess PV production would be compensated at a price less than retail rates. Our analysis indicates that, even at relatively high PV penetration levels, such an approach would not significantly erode the value of PV for PG&E and SCE customers, provided that the net excess PV generation is compensated at a price equal to or greater than avoided wholesale generation costs. This type of compensation mechanism, however, would not eliminate the variability in PV value across customers that is observed under current net metering tariffs.

7. ACKNOWLEDGMENTS

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