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Are Photovoltaic Systems Worth More to Residential Consumers on Net Metered Time-of-Use Rates?

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Abstract

This paper compares the value of photovoltaic (PV) systems to residential customers under Time-of-Use (TOU) rates versus non-TOU (standard) rates. Key factors that determine the difference in value include: the fundamental rate structure, whether on not the customer changes from a standard to a TOU rate, the customer's load profile (if there is a rate switch), and the size of the PV system relative to the customers overall electricity demand. Results indicate that TOU metering for a residential customer in San Jose, CA (Pacific Gas and Electric Company) increases the value of PV by about 10 percent for customers that did not switch rates. Results also suggest that, depending upon the customer's original load profile and size of the PV system, the added value of switching from a standard to a TOU rate and then adding a PV system can result in a bundled value increase from 20 percent to over 100 percent. The paper finds that, assuming that customers are economically indifferent between standard and TOU rates prior to adding PV, TOU rates increase the value of PV for most locations in the U.S. with the increase ranging from negligible to over 50 percent.

Background

There is a growing interest among individuals and companies in photovoltaic (PV) systems as an alternative to conventional utility electric supply. A challenge that has prevented the wide-spread adoption of PV, however, is its high initial capital cost.

Over the last several years, this situation has changed in several ways. First, a number of states now provide capital cost buydowns, tax credits, and other financial incentives to reduce the net capital cost of PV paid by the consumers. Second, electric rates in a number of locations have increased. Together, these two factors have created a situation where PV has a positive net economic value in many locations.

Even with these two factors, however, customers must have a long-term perspective in order to justify an investment in PV. As a result, analysts as well as sales people are looking for ways to increase the value of PV to the consumer in order to shorten the required investment period.

Introduction

A broad consensus is beginning to emerge that utilities should be encouraged/required to offer all of their customers TOU rates. While the Energy Policy Act of 2003 was not passed by Congress, this consensus was reflected in the bill's language requiring that "each electric utility shall offer each of its customer classes, and provide individual customers upon customer request, a time-based rate schedule under which the rate charged by the electric utility varies during different time periods and reflects the variance, if any, in the utility's costs of generating and purchasing electricity at the wholesale level [1]." Similar provisions are likely to be included in energy legislation proposed during 2004. Solar electric power advocates believe that, by recognizing the inherently higher value of electricity generated in the middle of the day, this could substantially increase the value of PV electricity production when implemented in conjunction with net metering [2].

Furthermore, a number of dealers and others in California have made public claims (such as at solar energy conferences) that Pacific Gas and Electric customers can obtain 40 percent more value from their PV system if they are on a Time-of-Use (TOU) rate structure.

Objective

The objective of this paper is to determine if PV systems have greater value under TOU rates that under standard rates. The analysis is performed by quantifying the electric bill savings for PV systems on residential TOU and standard net metered rates and comparing the results. The paper begins with a hypothetical example that illustrates the importance of load data when a rate change is involved, presents results for a customer in San Jose, CA, and concludes with results for customers throughout the U.S.

Simple Example

The objective of this study is to determine if PV systems have greater value under TOU rates that under standard rates. It is tempting to perform two calculations to compare the value of PV under the two different rate structures: calculate the bill savings using the standard rate structure, calculate bills savings using the TOU rate structure, and compare the two. If the analysis is performed in this manner, however, the results can be erroneous because it does not account for potential cost/savings of switching from one rate to another.

Consider a simple example. A customer consumers 10,000 kWh per year and is considering the installation of a PV system that produces 5,000 kWh per year (half of which is before noon and half of which is afternoon). The standard rate charges $0.10 per kWh for all consumption; the TOU rate charges $0.20/kWh from noon to 6 PM and $0.05/kWh for all other hours.

Table 1 presents a simplistic bill savings analysis. It multiplies PV system output by the time-corresponding rate. It suggests that PV systems have 25 percent higher value on the TOU rate than the standard rate.

This simplistic analysis will be accurate if it the customer does not change rate structures. In many cases, however, the customer is currently on a standard rate structure (either the TOU rate does not exist or the customer is not currently on the TOU rate). Thus in order to understand the value of PV combined with TOU rates, it is important to quantify the impact of adding a PV system both with and without a change in rate structures.

Table 1. Simplistic bill savings analysis.

	Noon to 6 PM	6 PM to Noon
PV Output	2,500	2,500
Rates ($/kWh)		
Standard	$0.10	
TOU	$0.20	$0.05

	Standard	TOU
Savings	$500	$625

Table 2 presents a more accurate analysis by analyzing the cost/value of the rate switch in addition to the value of the PV. The first column presents results for a customer with a high peak load, the second column for a customer with a constant load, and the third column for a customer with an "economically indifferent" load. Results indicate that the value of the PV result depends upon the customer's load profile. The high peak load customer has 25 percent less value, the constant load customer has 50 percent more value, and the "economically indifferent" load customer has 25 percent more value (which is the same result simplistic analysis).

Table 2. Detailed bill savings analysis.

	Customer w/ Peak Afternoon Load	Customer w/ Constant Load	Customer w/ Peak Morning and Evening Load
Load (kWh)			
Noon-6PM	5,000	2,500	3,333
6PM- Noon	5,000	7,500	6,667
PV Output (kWh)			
Noon-6PM	2,500	2,500	2,500
6PM- Noon	2,500	2,500	2,500
Load - PV Output (kWh)			
Noon-6PM	2,500	0	833
6PM- Noon	2,500	5,000	4,167
Electric Rate ($/kWh)			
Standard	$0.10	$0.10	$0.10
TOU			
Noon-6PM	$0.20	$0.20	$0.20
6PM- Noon	$0.05	$0.05	$0.05
Current Bill ($/year)			
Standard	$1,000	$1,000	$1,000
TOU	$1,250	$875	$1,000
Bill With PV System			
Standard	$500	$500	$500
TOU	$625	$250	$375
Bill Savings			
Change from Standard to TOU Rate (No PV)	($250)	$1,25	$0
Add PV – Standard Rate	$500	$500	$500
Add PV – TOU Rate	$625	$625	$625
Add PV & Change from Standard to TOU Rate	$375	$750	$625

This clarifies the fact that one cannot simply design a tariff with high peak prices and assume that it is PV friendly. One either needs to know that customers will reduce their bills by switching to a TOU rate (which requires knowledge of load profiles) or it must be assumed that customers are economically indifferent between the old and new rates (i.e., they have the same current electric bill under both rates). Because detailed load profile information throughout the U.S. is difficult to obtain, the potion of this analysis that focuses on the U.S. will assume that customers are economically indifferent between being on a standard or TOU rate prior to adding the PV system.

Northern California Customer

Residential customers served by Pacific Gas and Electric Company (PG&E) are a useful customer to present detailed analytical results for several reasons. First, they represent a particularly important market for residential grid-connected PV systems in the U.S. because the economics are attractive and there are a lot of customers. Second, PG&E has an existing TOU rate in place for residential customers (albeit one of the most complex time-of-use residential rates in the U.S. because it has both quantity-based and time-based charges). Thus, this section presents a detailed analysis of a customer in San Jose, CA (PG&E territory). It compares the value of the PV assuming (1) there is no rate change; and (2) there is a rate change.

Rate Data

PG&E's standard residential rate is the E-1 rate and its TOU rate is the E-7 rate [3]. As shown in Table 3, the E-1 and the E-7 are both composed of an energy charge, which can vary by season and time period for the E-7 rate, and a quantity-based (tier) charge, which is based on the location-specific quantity of electricity consumed in any month. In addition, the E-7 has a meter charge, and the two rates have minimum bills and a 10 percent bill discount.[1]

[1] The E-7 rate has an additional meter charge of $0.1281 per day. In addition, there are bill discounts and minimum bills associated with these rates.

Table 3. E-1 and E-7 rate schedules ($/kWh).

			Schedule E-1 (Standard Rate)		Schedule E-7 (TOU rate)			
			All Year		Summer (May – Oct.)		Winter (Nov. – April)	
	Consumption Based Charges				Peak 12-6 pm weekdays	Off-Peak All other hours	Peak 12-6 pm weekdays	Off-Peak All other hours
Time Based Charges			$0.1259		$0.3079	$0.0778	$0.1090	$0.0812
(% Baseline)[2]								
0% – 100%	$0.0000		$0.1259		$0.3079	$0.0778	$0.1090	$0.0812
101% - 130%	$0.0173		$0.1432		$0.3252	$0.0952	$0.1264	$0.0985
131% - 200%	$0.0685		$0.1945		$0.3765	$0.1464	$0.1776	$0.1498
201% - 300%	$0.1125		$0.2384		$0.4204	$0.1903	$0.2215	$0.1937
>300%	$0.1323		$0.2582		$0.4402	$0.2101	$0.2413	$0.2135

Problem Formulation

TOU net metering in California is performed on an annual basis. In addition, if PV output exceeds consumption during any given period, the energy value is credited at the retail rate during that period. The bill is then trued up to account for minimum bills on an annual basis. As a result, assuming that the PV production does not cause the customer to pay the minimum bill, the customer's electric utility bill with a PV system with either a standard or TOU rate is calculated as follows.[3]

$$Bill^{schedule} = \sum_{month}\sum_{period}\sum_{tier}\left(R^{\text{schedule}}_{month,period} + R^{\text{schedule}}_{tier}\right)\left(Q_{month,period,tier} - PV_{month,period,tier}\right) + Meter^{schedule} \quad (1)$$

where R is the rate, Q is the original quantity consumed, and PV is the PV system output. As depicted in Table 3, the rate is divided into two parts: one that is month, period, and rate schedule dependent and the other that is tier dependent (Tier column in Table 3). The formulation is presented in this manner to more conveniently summarize results.

Equation (1) can be rearranged into the current bill minus the PV value.

[2] Consumption based charges are based on the customer's consumption relative to the allowable baseline quantities. PG&E baseline quantities range from 7 to 32 kWh per day depending upon location, season, and type of space heating.

[3] A model such as the Clean Power Estimator accounts for all of these factors, including minimum bills and bill discounts.

$$Bill^{schedule} = Current\ Bill - \underbrace{\overbrace{\sum_{month}\sum_{period} R^{schedule}_{month,period} PV_{month,period}}^{\text{Time-based}} - \overbrace{\sum_{month}\left[\sum_{tier} R^{schedule}_{tier} PV_{month,tier}\right]}^{\text{Quantity (Tier)-based}}}_{\text{PV Value}} \quad (2)$$

where *Current Bill* is calculated using Equation (1) with all PV elements equal to 0.

As discussed earlier, the accurate way to calculate the added value of PV on a TOU rate is to compare the bill savings of PV on a standard rate to the bill savings on a TOU rate when switching from a standard rate.

Since the E-1 rate is constant throughout the year and the Quantity (Tier)-based PV value is the same for both the E-1 and the E-7 rates, the added value of being on an E-7 rate equals the change in bill due to a change in rate structure plus the difference in the time-based value of PV.

$$\text{Added Value} = \left(Current\ Bill^{E-1} - Current\ Bill^{E-7}\right) + \left(\sum_{month}\sum_{period} R^{E\text{-}7}_{month,period} PV_{month,period} - R^{E-1} PV_{annual}\right) \quad (3)$$

Equation (3) suggests that there are TWO reasons that PV may have a higher value using a TOU rate:

1. The consumer may generate value by switching from an E-1 to an E-7 rate independent of whether or not the PV is installed
2. The added value of PV is solely a function of PV output and energy prices by month and period (as long as minimum bills are not in effect)

Case 1: No Value to Rate Change

Equation (3) can be used to calculate the average increase of the E-7 over the E-1 by assuming that there is no value to changing rate structure (Current Bill on E-1 equals Current Bill on E-7) and then dividing by the annual PV output. As shown below, the added value ($/kW) equals the weighted average E-7 minus the E-1.

$$Added\ Value = \overbrace{\sum_{month}\sum_{period} R^{E-7}_{month,period} \%PV_{month,period}}^{\text{Weighted-average E-7}} - R^{E-1} \quad (4)$$

As shown in Table 4, the added value of TOU net metering for a south facing system is between 9 and 18 percent, depending upon the customer's original consumption. Since many customers installing PV in California tend to have high utility bills, the percent savings for most people will be closer to the 9 percent added value.

Table 4. Added value with TOU net metering.

	PV Output	E-7 Rate	
		Lowest Tier	Highest Tier
Summer On-Peak	28%	$0.3079	$0.4402
Summer Off-Peak	32%	$0.0779	$0.2102
Winter On-Peak	16%	$0.1091	$0.2414
Winter Off-Peak	24%	$0.0812	$0.2135
E-7 (Weighted Avg.)		$0.1488	$0.2811
E-1		$0.1259	$0.2582
Increase in Value		18.2%	8.9%

Discussion

It was stated earlier in the paper that some market participants claim that customers can receive 40 percent more value from PV on the TOU rate. Do the results in the previous section imply that these are inaccurate claims? Not necessarily.

The assumption above was that there was no economic effect due to changing rate structures. In fact, this will rarely be the case. For example, customers with high peak period consumption will lose value by switching to a TOU rate while customers with low peak period consumption will gain value by changing to a TOU rate.

The Clean Power Estimator [4] has typical load profiles embedded into the program that are associated with the various rate structures. These load profiles were obtained during California's restructuring process that utilities were required to publicly release. Figure 1 presents the January and July load profiles for a typical E-1 customer.

The Estimator can be run to compare the value of a rate structure change. Based on the E1 load profile, the customer's utility bill is reduced between 8 and 10 percent depending upon their tier level.

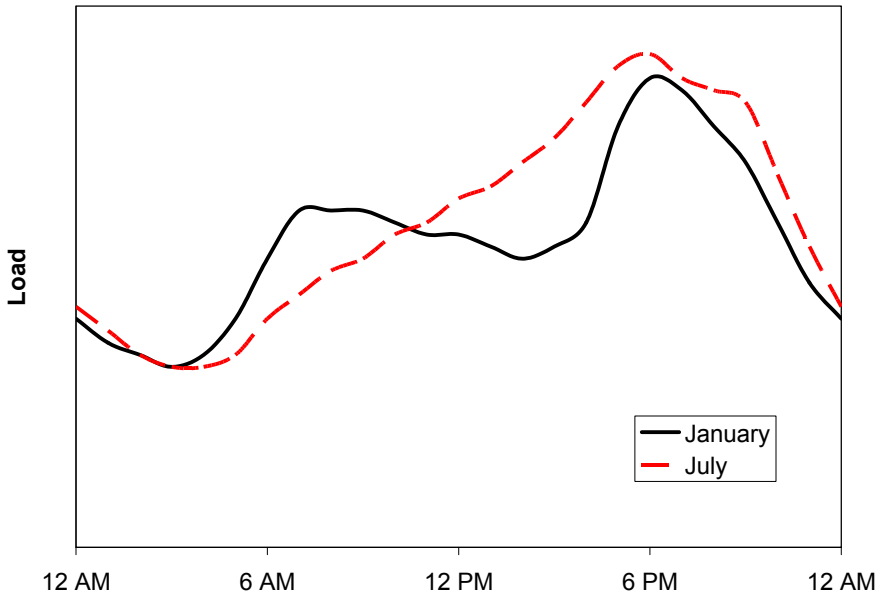

Figure 1. Load profile for typical PG&E E-1 customer.

As a result, it is simple to construct scenarios where customers can double the value of a PV system by switching to a TOU rate structure. The upper portion of Figure 2 presents the utility bill savings versus PV system size for a PG&E customer with a $4,000 annual bill switching from a standard E-1 rate to a TOU E-7 rate. The dark blue portion of the graph presents the basic value (i.e. the bill savings associated with a PV system on an E-1 rate), the light blue presents the value of switching from an E-1 to an E-7 (it is independent of PV system size), and the medium blue presents the added value due to the fact that the PV is metered on an E-7 rather than an E-1 rate.

As an example, suppose that a customer wants to cut their utility bill in half. The dashed lines in the figure suggest that they can achieve this by either switching to an E-7 (TOU) rate and adding 3.5 kW of PV or staying on the E-1 rate and adding almost a 5 kW of PV.

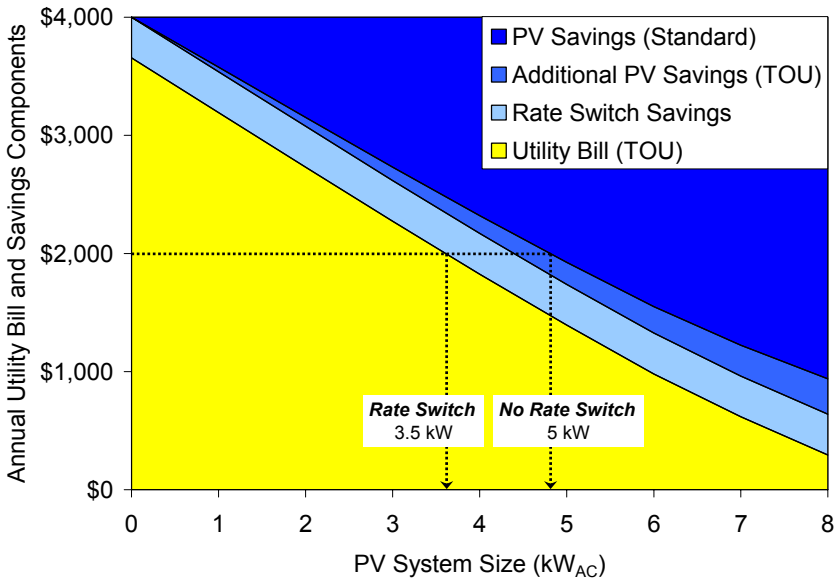

Figure 2. Switching from standard to TOU rate increases PV's value (customer in San Jose, CA with $4,000 annual bill on standard rate).

Figure 3 presents the percentage added value of the PV on an E-7 versus an E-1 (where added value equals the rate change plus additional PV value). As can be seen in the figure, when the PV is small relative to the total bill, one can more than double the value of the PV due to the value of the rate switch. Notice that as the PV system size goes to zero, the percentage value goes to infinity.

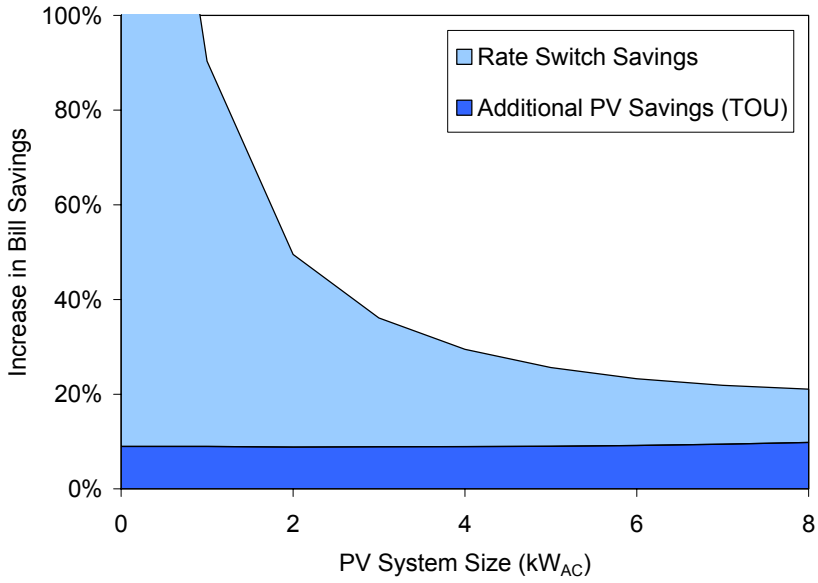

Figure 3. Percentage increase in utility bill savings versus PV size (customer in San Jose, CA with $4,000 annual bill on standard rate).

Switch From TOU to Standard Rate

A corollary to the increase in value due to the rate switch is the loss in value due to a rate switch in the other direction. For example, assume that the customer is currently on a TOU rate structure. PG&E assess customers a one-time meter charge of $277 for a bi-directional TOU meter whether or not the customer currently has a standard TOU meter; there is no charge for a non-TOU bi-directional meter.[4]

In this example, consider a customer with a small annual utility bill ($600 per year) currently on an E-7 TOU rate. It may be tempting for the customer to assume that the one-time $277 bi-directional TOU meter charge is excessive compared to the value of the PV system. As shown in the figure, however, a customer can either stay on the E-7 TOU rate (and incur the $277 fee for the bi-directional TOU meter) and add 1.1 kW of PV or they can switch to a non-TOU rate (so they do not incur the $277 meter charge) and install 1.7 kW of PV. That is, paying the one-time $277 meter fee is economically comparable to an additional 0.6 kW of PV. Note that these results are highly dependent upon the customer's actual load profile. Results will change for customers with profiles that differ from the typical profile.

[4] Customers are assessed this charge even if they currently have a TOU meter that is not capable of net metering.

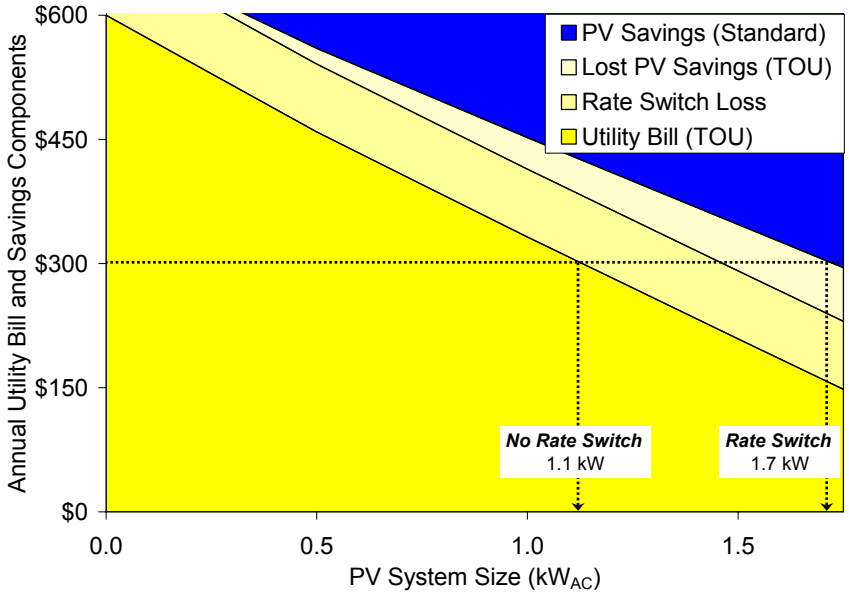

Figure 4. Switching from TOU to standard rate decreases PV's value (customer in San Jose, CA with $600 annual bill on standard rate).

Results Throughout U.S.

The results presented so far in this paper have focused on a detailed analysis of TOU rates for Northern California customers. This section presents results for TOU rates throughout the U.S.

The analysis is based on the following assumptions:

- Customers are residential customers
- Customers are revenue neutral between standard and TOU rates so that there is no financial cost or benefit of switching from a standard to a TOU rate.
- Customers consume 10,000 kWh per year
- A 2 kW_{DC} PV system is installed
- There is annual net metering, thus avoiding any potential issues of lost power due to overproduction
- TOU rates with demand charges are excluded

The Clean Power Estimator is used to perform the following calculations:

1. Calculate current and proposed utility bill on standard rate
2. Calculate utility bill savings on standard rate (current minus proposed utility bill)
3. Calculate the current and proposed utility bill on TOU rate
4. Calculate TOU utility bill savings (current minus proposed utility bill)
5. Calculate increase in value due to TOU metering (divide utility bill savings on TOU rate by utility bill savings on standard rate and subtract 1)

Figure 5 presents the percentage increase in utility bill savings due to TOU metering. The figure indicates that almost all locations have an increase in value due to TOU

metering with the increase being over 50 percent in some locations. It is important to note that this increase in value is due to the value of the PV on the TOU rate and not due to a rate structure change. That is, unlike the previous section of the paper, it was assumed that there is no financial cost or benefit of switching from a standard rate to a TOU rate.[5]

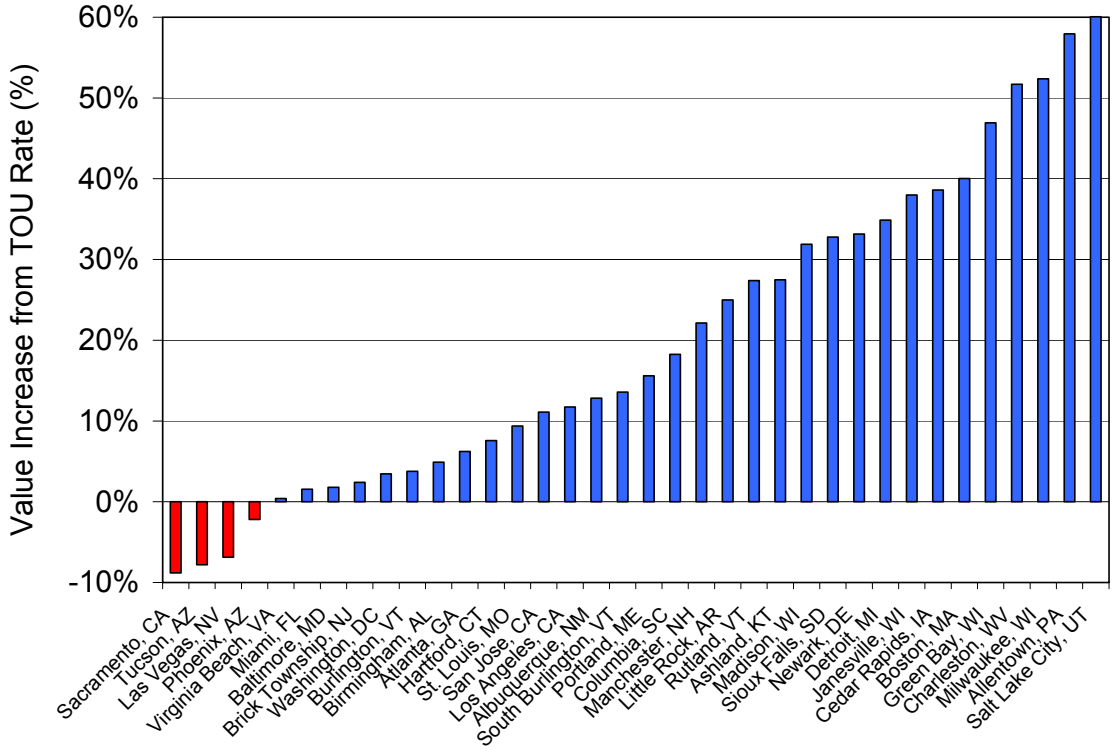

Figure 5. Percentage increase in utility bill savings due to TOU metering.

Conclusions

The objective of this paper was to determine if PV systems have higher value under Time-of-Use (TOU) rates than under non-TOU (standard) rates. Results indicate that TOU metering for a customer in San Jose, CA (Pacific Gas and Electric Company) increases the value of PV by about 10 percent. Results also suggest that, depending upon the customer's original load profile and size of PV system, the added value of switching from a standard to a TOU rate and then adding a PV system can result in a bundled value increase from 20 percent to over 100 percent. The paper finds that, assuming that

[5] Of the few locations where value is reduced, the comparison for two locations (Sacramento, CA and Phoenix, AZ) are based on standard rates with tier charges versus TOU rates that do not have tier charges (this may explaining why two of the four locations have reduced value on a TOU rate). In terms of the other locations where value is reduced (Tucson, AZ and Las Vegas, NV), it may be due to the fact that these are hot climates where air conditioning needs are basic necessities such that the utility systems are designed for high peak loads during hot times; further investigation is needed in this area.

customers are economically indifferent between standard and TOU rates prior to adding PV, TOU rates increase the value of PV for most locations in the U.S. with the increase ranging from negligible to over 50 percent.

References

[1]. Title XII (Electricity), Sec. 1252(a) of The Energy Policy Act of 2003; available at http://energy.senate.gov/legislation/energybill2003/energybill2003.cfm.

[2]. Solar Energy Bill Provisions Released, http://www.solaraccess.com/news/story?storyid=5561.

[3]. Pacific Gas and Electric Company tariffs, www.pge.com/customer_services/business/tariffs.

[4]. Clean Power Estimator, www.clean-power.com.