The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California

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July 2007

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Presentation Outline

1. **Motivation and Scope**
2. **Data and Methodology**
3. **Results**
   a) Variation in Bill Savings for Commercial PV Systems in California
   b) The Effects of Specific Differences in Rate Design and Customer Characteristics
   c) The Value of Offering Optional “PV-Friendly” Rates
   d) The Value of Net Metering
4. **Policy Implications and Future Work**

Motivation and Scope

- **Motivation:** To create a self-sustaining market, grid-connected PV may have to be competitive with retail electricity rates; discussion of retail rate issues for PV has tended to focus more on net metering than on other elements of rate design
- **Objective:** Evaluate the impact of retail rate design on the customer-economics of grid-connected PV, focusing on commercial customers in California
- **Intended Audience:**
  - Regulators/policymakers who have a responsibility to design tariffs, and want to make those tariffs attractive to PV
  - End-use customers, PV retailers, and consultants who need to estimate the potential bill savings from PV installations

Utility Bill Savings from PV Are Affected by a Host of Factors

Rate design issues

- Size of demand charges relative to energy charges
- Type of demand charge
- Type of energy charge
- Time-of-day (TOD) period definition for demand charges
- Time-of-use (TOU) price spread between peak/off-peak for energy charges
- Availability of multiple optional rates, and availability of net metering

Other issues

- Revenue requirements of the utility and rate class
- Size of PV system relative to building load
- Customer load shape
- PV production profile

Research Questions

1. **What is the overall variation in bill savings among commercial PV systems in California?**
2. **How much of the variation is attributable to differences in *rate design*, and which issues are most critical?**
3. **To what extent do optional "PV-friendly" rates provide value for commercial PV systems?**
4. **What is the value of net metering, as currently offered in California?**

Data and Methodology

- **We compute utility bill savings across 20 current commercial rates offered by the state's five largest electric utilities** (PG&E, SCE, SDG&E, LADWP, and SMUD)
- **Using data from a diverse sample of 24 actual commercial PV installations in California:**
  - One year of contemporaneous 15-minute interval customer load and PV production for each site
- **We compare bill savings in terms of the reduction in the annual utility bill *per kWh* of PV electricity produced ($/kWh)**
- **We scale PV data to calculate the value of PV at specific PV penetration levels for each site**
  - **PV Penetration Level = annual PV production as a percentage of gross building load**
  - Focus on results at 2% and 75% PV penetration, as representative boundary cases

Rate Schedules Analyzed

Rates Evaluated in Analysis

Utility	Rate Name	Energy Charge Type	Demand Charge Type	
			Facility Charge	Demand Charge
LADWP	A-2, A	Flat	Annual, Fixed	Monthly, Seasonal
	A-2, B / A-3, C	TOU	Annual, Fixed	TOD, Seasonal
PG&E	A-1	Seasonal	-	-
	A-6	TOU	-	-
	A-10	Seasonal	-	Monthly, Seasonal
	A-10 TOU	TOU	-	Monthly, Seasonal
	E-19	TOU	Monthly, Fixed	TOD, Seasonal
	E-20	TOU	Monthly, Fixed	TOD, Seasonal
SCE	GS-2, Non-TOU	Seasonal	Monthly, Fixed	Monthly, Seasonal
	GS-2, TOU Option A	TOU	Monthly, Fixed	-
	GS-2, TOU Option B	TOU	Monthly, Fixed	Monthly, Seasonal
	TOU-GS-3 Option A	TOU	Monthly, Fixed	-
	TOU-GS-3 Option B	TOU	Monthly, Fixed	TOD, Seasonal
	TOU-8	TOU	Monthly, Fixed	TOD, Seasonal
SDG&E	AL-TOU	TOU	Monthly, Fixed	TOD, Seasonal
	A-6 TOU	TOU	Monthly, Fixed	TOD, Seasonal
SMUD	GS-Demand	Seasonal	Annual, Fixed	-
	GS-TOU3	TOU	Annual, Fixed	TOD, Seasonal
	GS-TOU2	TOU	Annual, Fixed	TOD, Seasonal
	GS-TOU1	TOU	Annual, Fixed	-

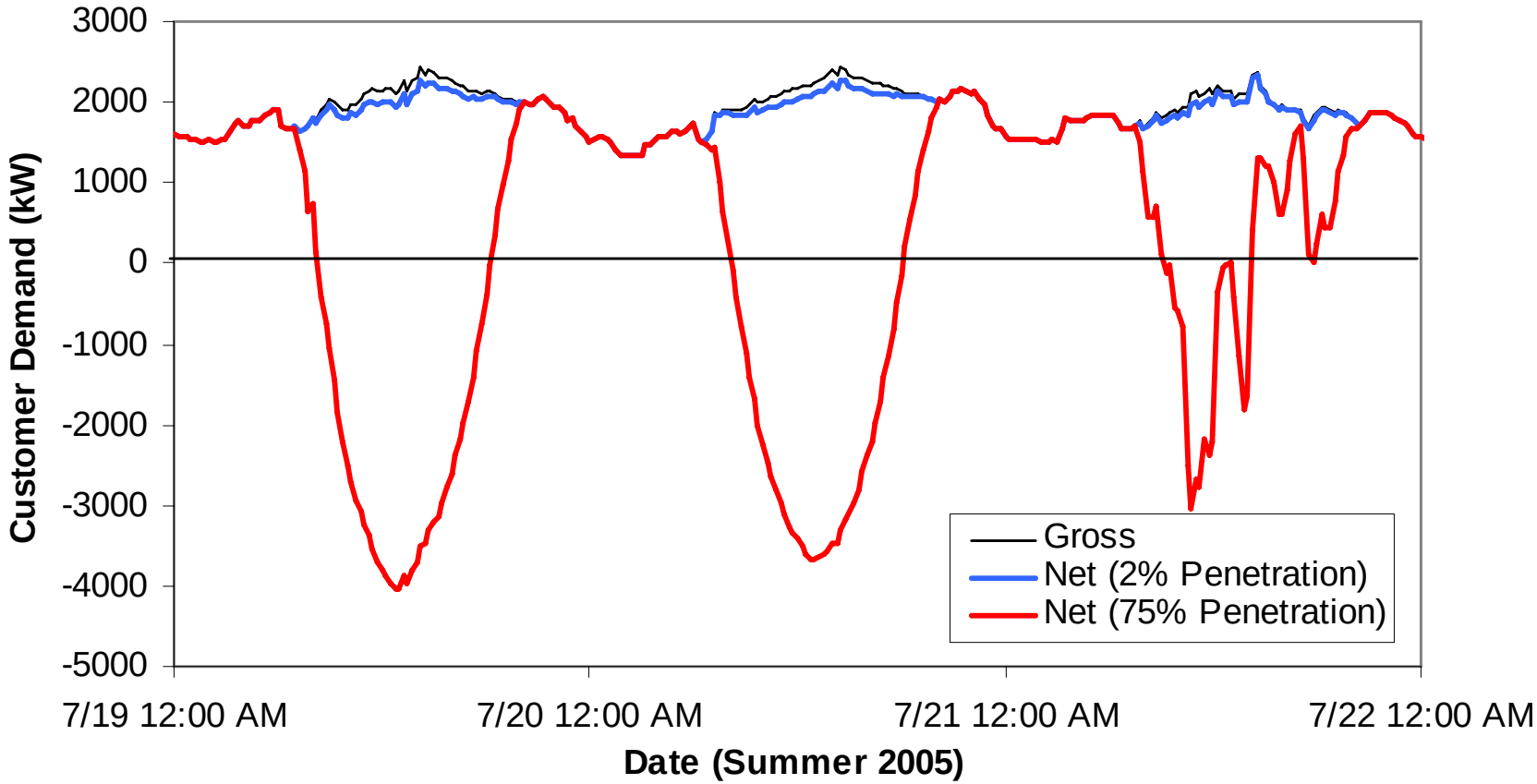
Energy Charges ($/kWh)

- Flat
- Seasonal
- Time-of-use (TOU)

Demand Charges ($/kW)

- **Annual:** Maximum demand in previous twelve months
- **Monthly:** Maximum monthly demand
- **Time-of-day (TOD):** Maximum monthly demand during specific TOD periods
- Any of the above may be based on $/kW rates that are **fixed** or that vary **seasonally**

Illustrative Example of 15-Minute Demand Data, at 2 Levels of PV Penetration



Annual utility bill before PV: Calculated from gross demand

Annual utility bill with PV: Calculated from net demand

Value of PV: Difference in bills per unit of energy produced by PV

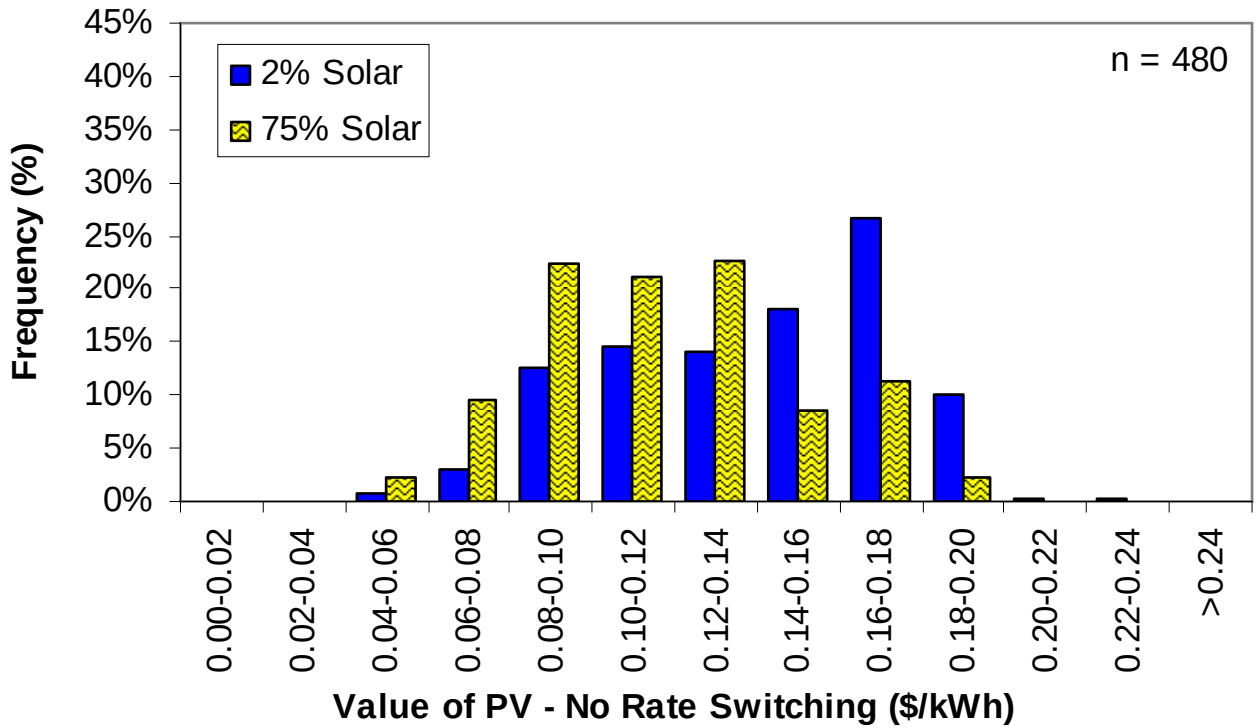
Research Questions

1. **What is the overall variation in the value of bill savings among commercial PV systems in California?**
   - Based on each utility's net metering rules
   - Assuming that customers remain on the same rate before and after installation of PV
2. How much of the variation is attributable to differences in *rate design,* and which issues are most critical?
3. To what extent do optional "PV-friendly" rates provide value for commercial PV systems?
4. What is the value of net metering, as currently offered in California?

The Rate-Reduction Value of PV Varies by a Factor of Four

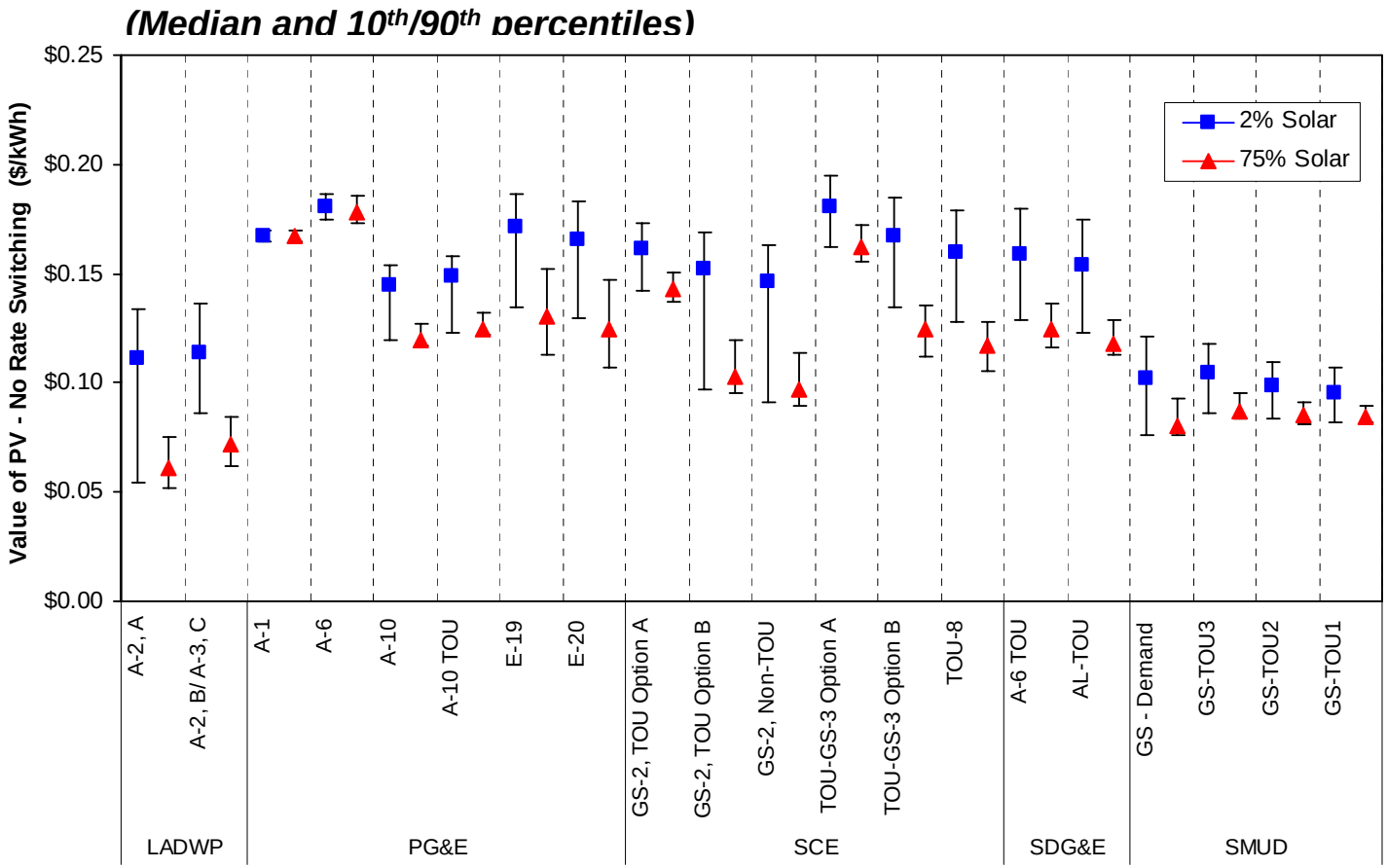
Figure shows the distribution in the rate-reduction value of PV across all combinations of customers and rate schedules

- Value of PV ranges from $0.05/kWh to $0.24/kWh
- Median value drops from $0.143/kWh at 2% PV penetration to $0.115/kWh at 75% penetration



Range in values reflects differences in: (1) rate structure, (2) revenue requirements, (3) customer load shape, and (4) PV production profile

The Rate-Reduction Value of PV Varies Widely Across Rates



Range of median values represents differences due to rates:

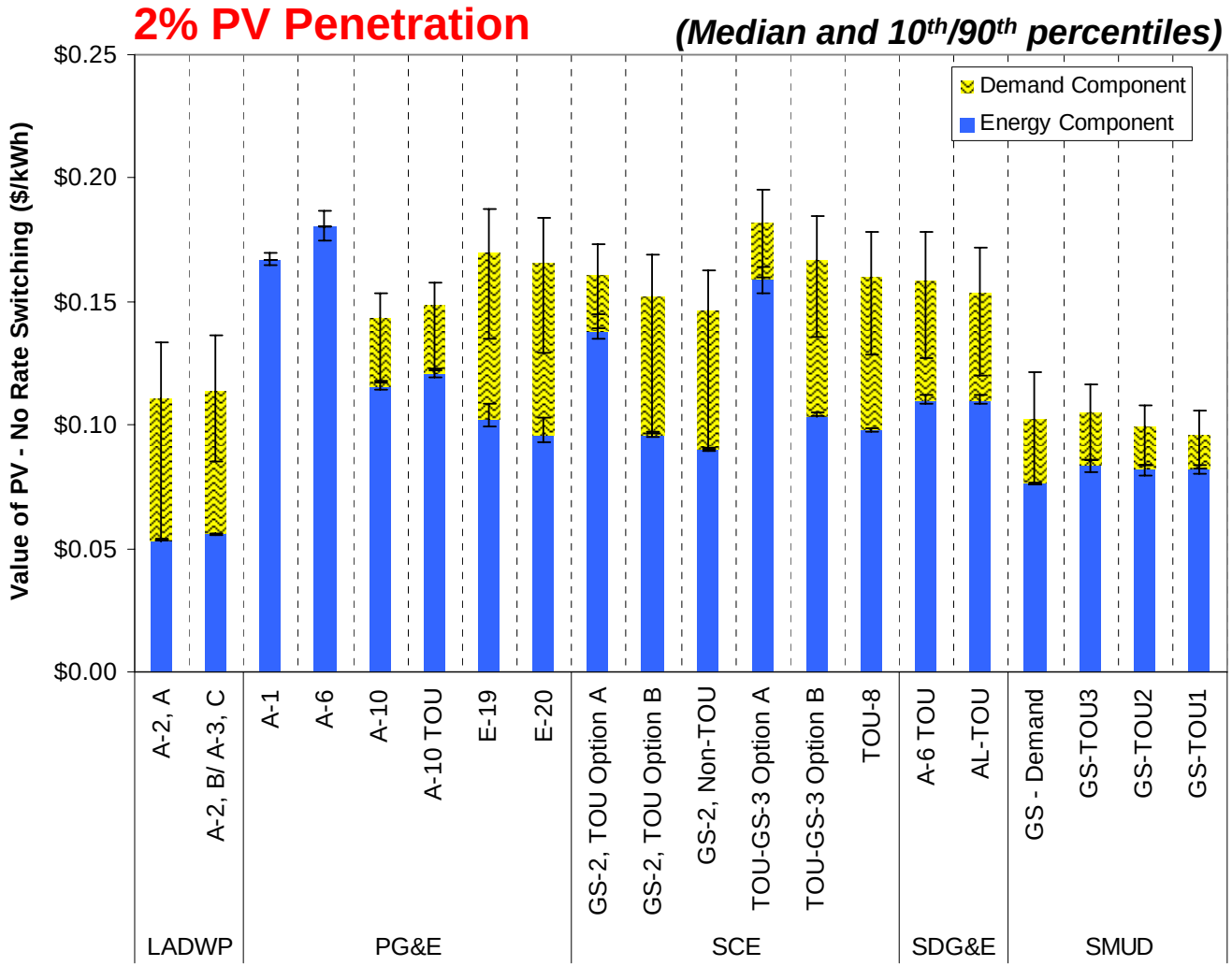
$0.10-$0.18/kWh (2%)

$0.06-$0.18/kWh (75%)

Drop off from 2% to 75% is much more pronounced for some rates than others

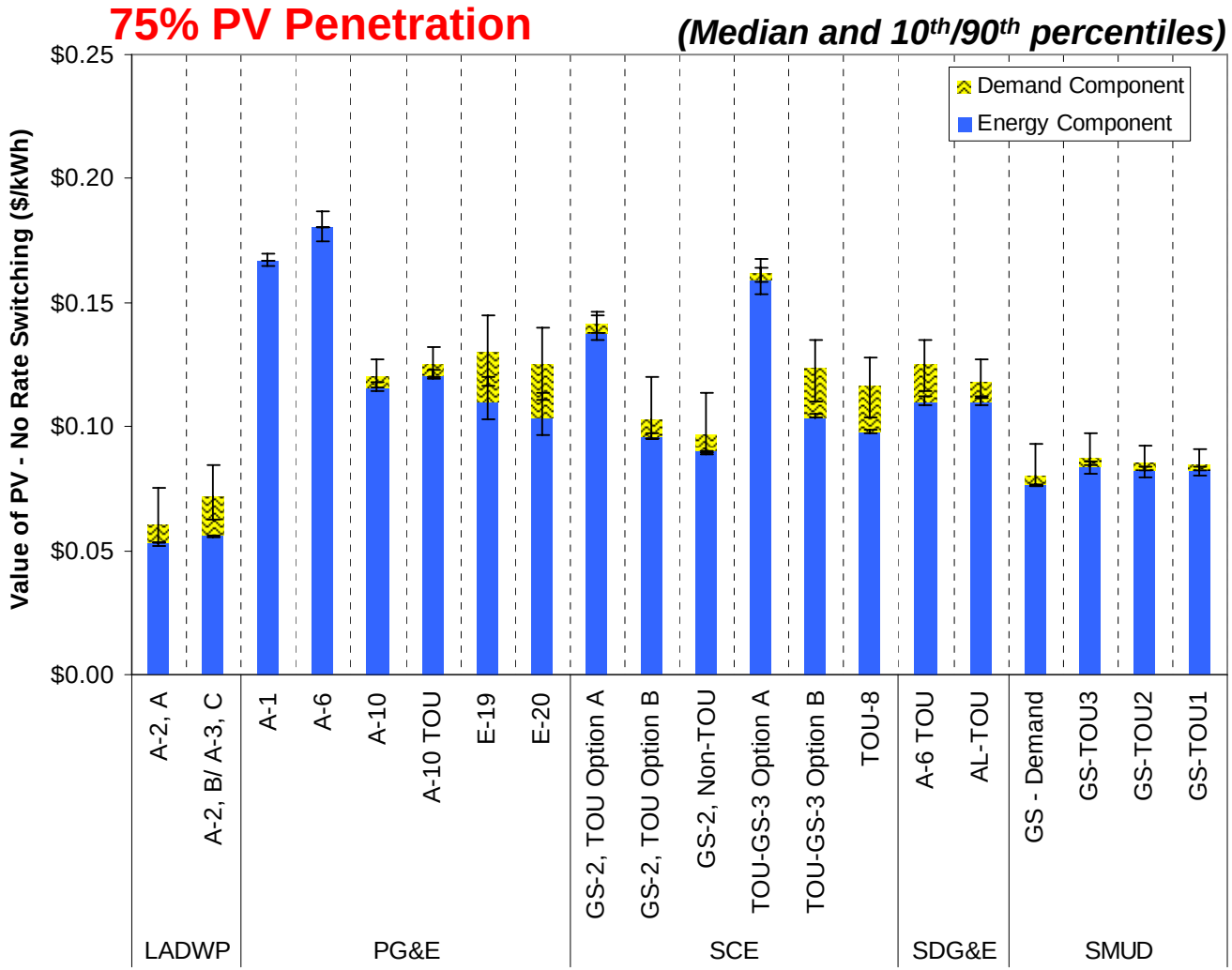
Percentile band is much larger for some rates than others

Demand Charge Savings Can be Substantial, at Low Levels of PV Penetration



- For some rates, >50% of the value of PV can come from reduction in demand charges at 2% PV penetration
- Demand charge reductions are highly customer-specific, however, as indicated by wide percentile bands

Demand Charge Savings Decline at Higher PV Penetration Levels, on a $/kWh Basis



- Rates with high demand charges become significantly less attractive at high PV penetration
- In comparison, energy charge savings vary little across PV penetration levels or customers

Research Questions

1. What is the overall variation in the value of bill savings among commercial PV systems in California?

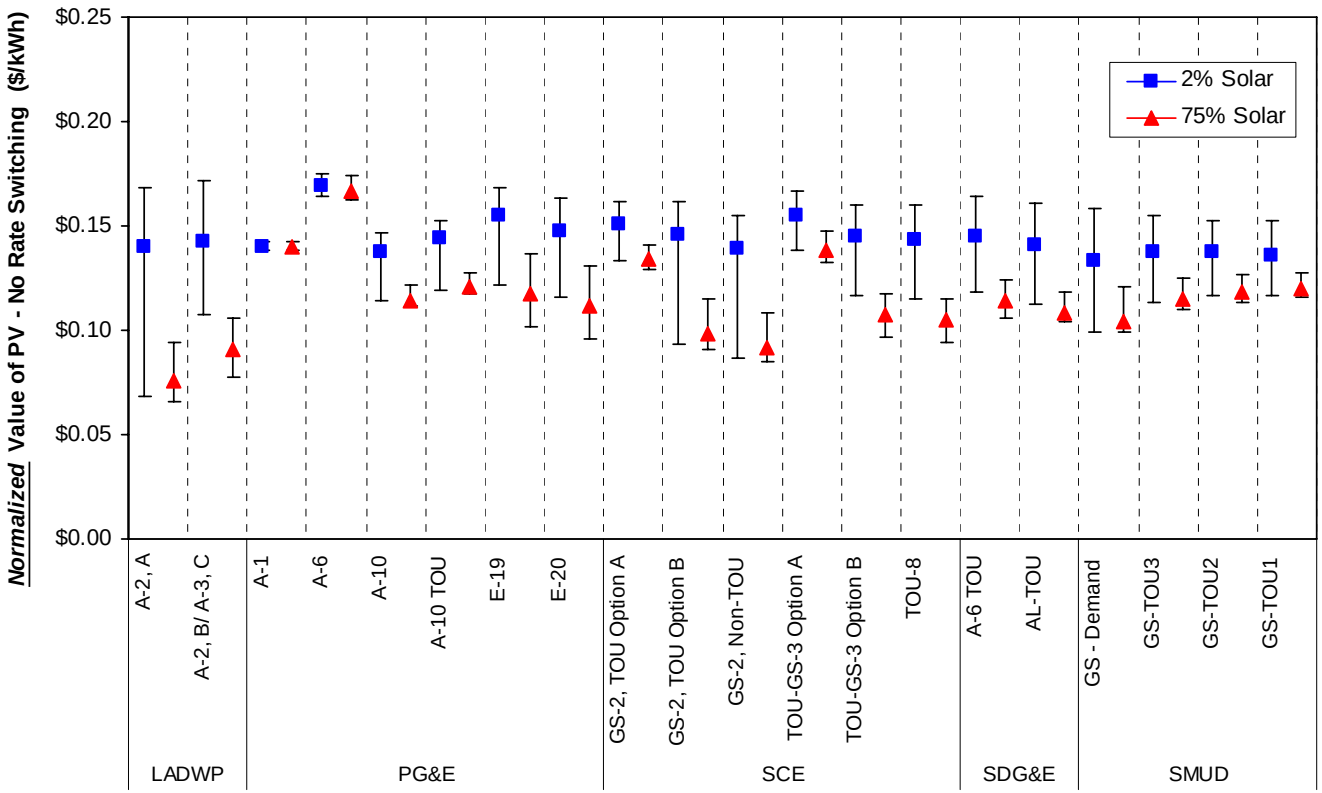
2. **How much of the variation is attributable to differences in *rate design*, and which factors are most critical?**

- To what extent do optional “PV-friendly” rates provide value for commercial PV systems?
- What is the value of net metering, as currently offered in California?

Normalizing for Differences in Revenue Requirements Reveals Impact of Rate Structure

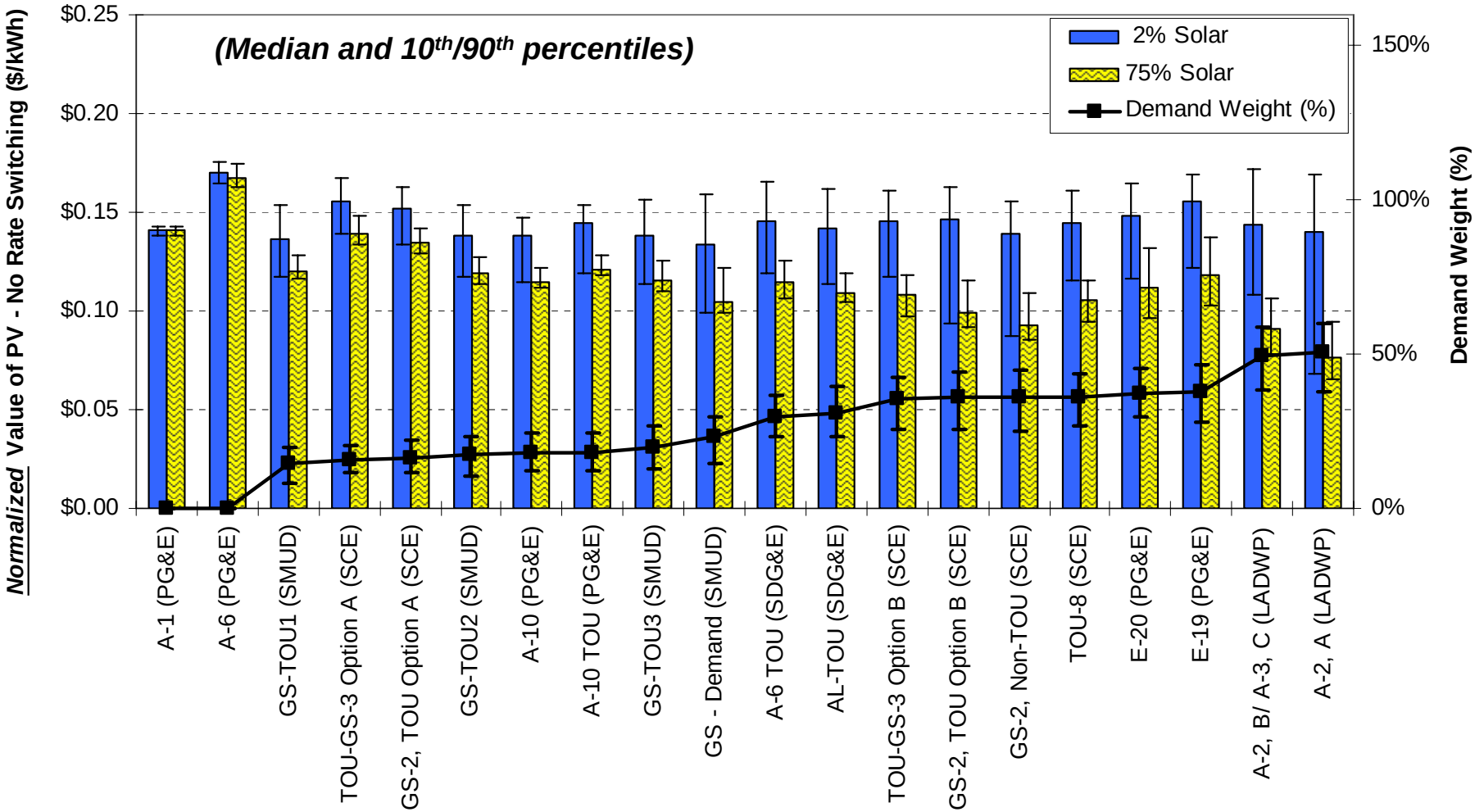
The figure shows the value of PV for each rate, when *normalized* based on the average cost of electricity prior to PV installation

- Shows that differences in rate structure are far more important at high PV penetration levels
- At low PV penetration levels, customer-specific issues predominate, as indicated by wide percentile bands



(Median and 10th/90th percentiles)

Rates with Low Demand Charges Are More Valuable at High PV Penetration

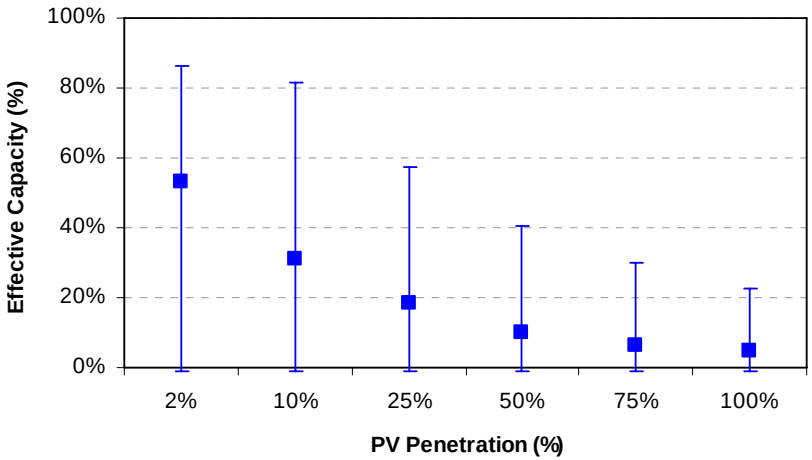


Demand Weight: **Cost of demand charges prior to PV installation as a percentage of the total average cost of electricity on each rate**

Demand Reduction Depends on PV Penetration and Definition of Demand

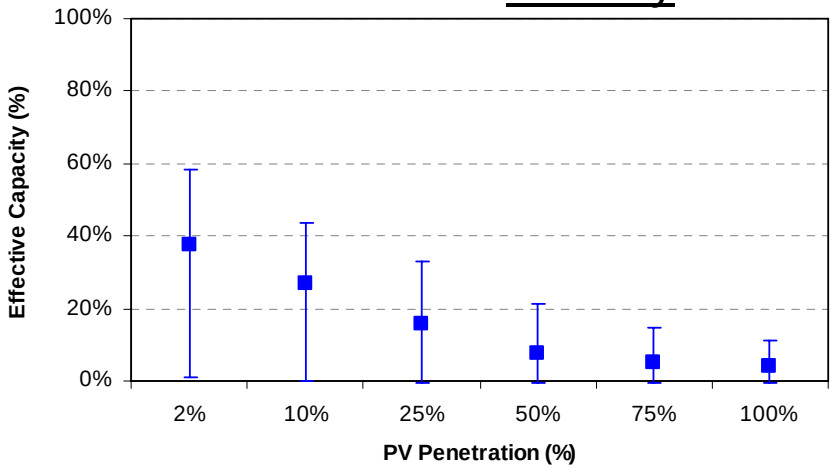
Effective Capacity: **Demand reduction as a percentage of maximum PV output**

Reduction in Maximum Annual Demand

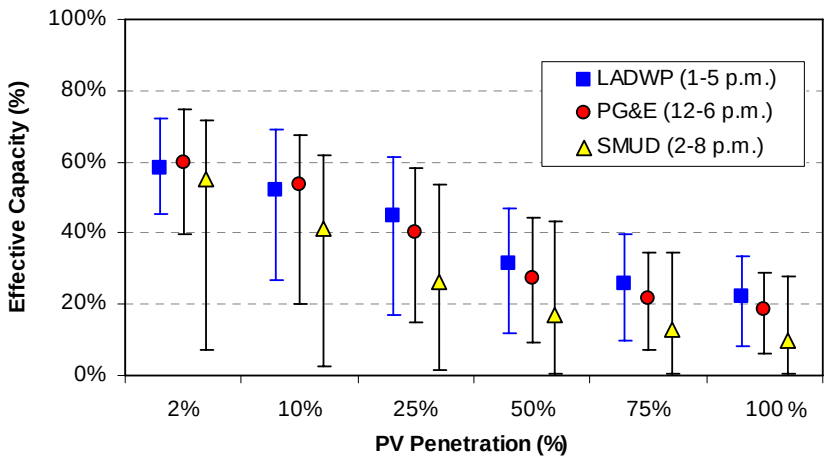


- Demand reductions are largest and least variable when focusing Summer Peak TOD
- Wide percentile bands indicate that differences in load shape and/or PV profile across the 24 customers have large effect

Reduction in Maximum Monthly Demand

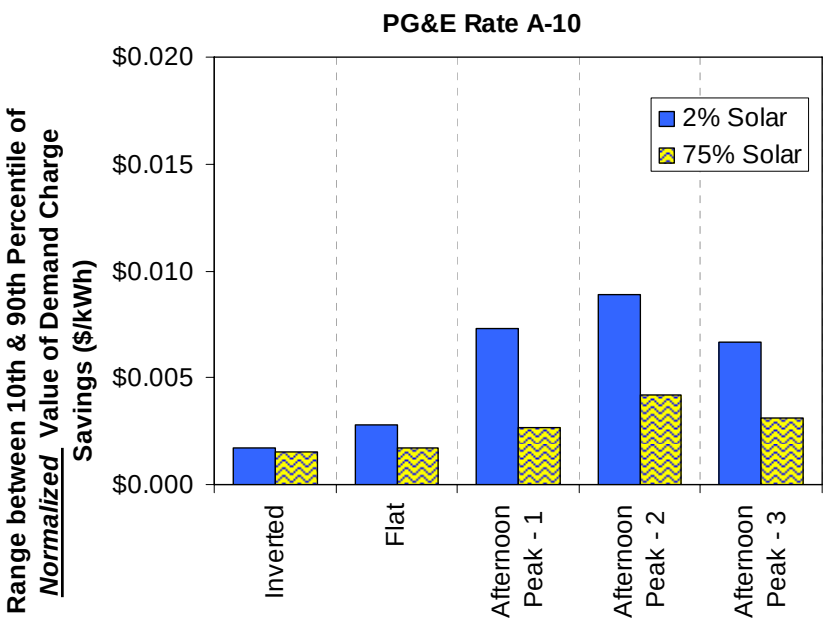


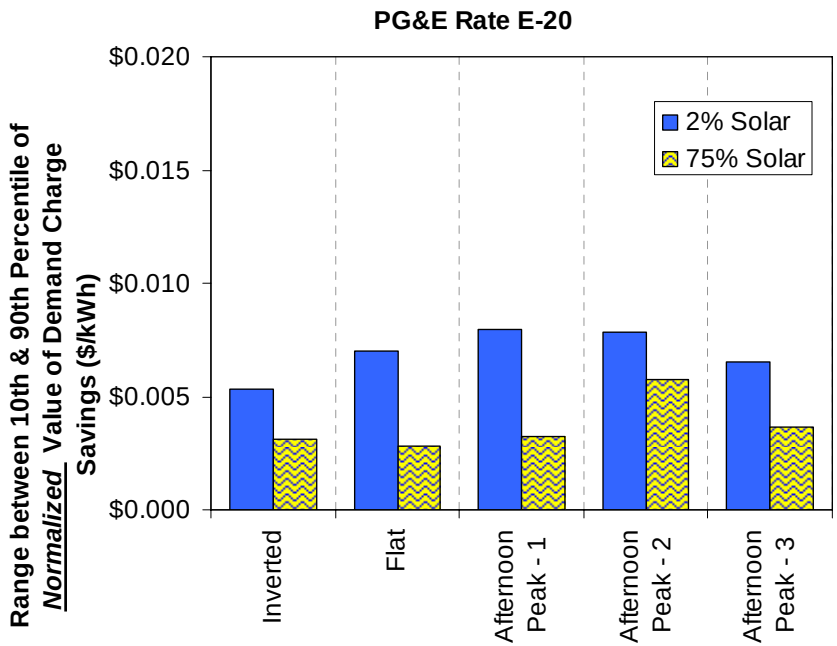
Reduction in Maximum Monthly Demand in Summer Peak TOD Period



Differences in Temporal PV Production Profiles Have Modest Impact on PV Value

To isolate the impact of differences in PV production profiles, we match each of the 24 PV datasets with five representative load profiles



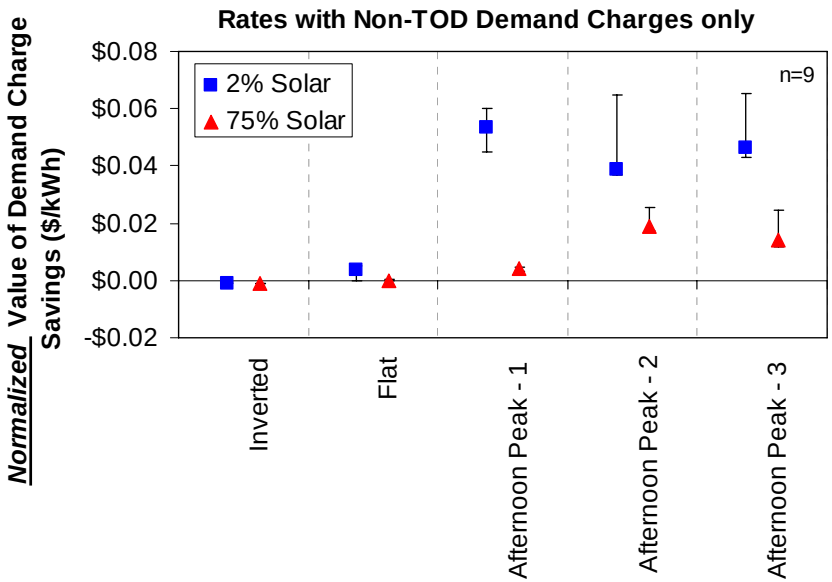


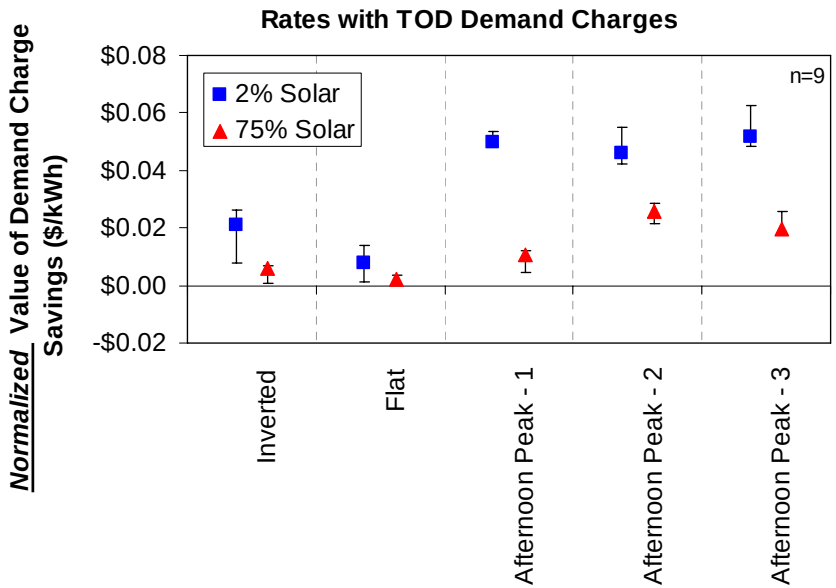
- The figures show the range between the 10th and 90th percentile values for each load profile
- We compare two rates with different types of demand charges
- The effect of differences in PV production profile is < $0.01/kWh
- The implication is that variation in the value of PV across customers is due primarily to differences in load profiles

Demand Charge Savings Are Much Lower for Facilities With Flat or Inverted Load Profiles

The figures compare demand charge savings for five representative customers across rates with and without TOD-based demand charges

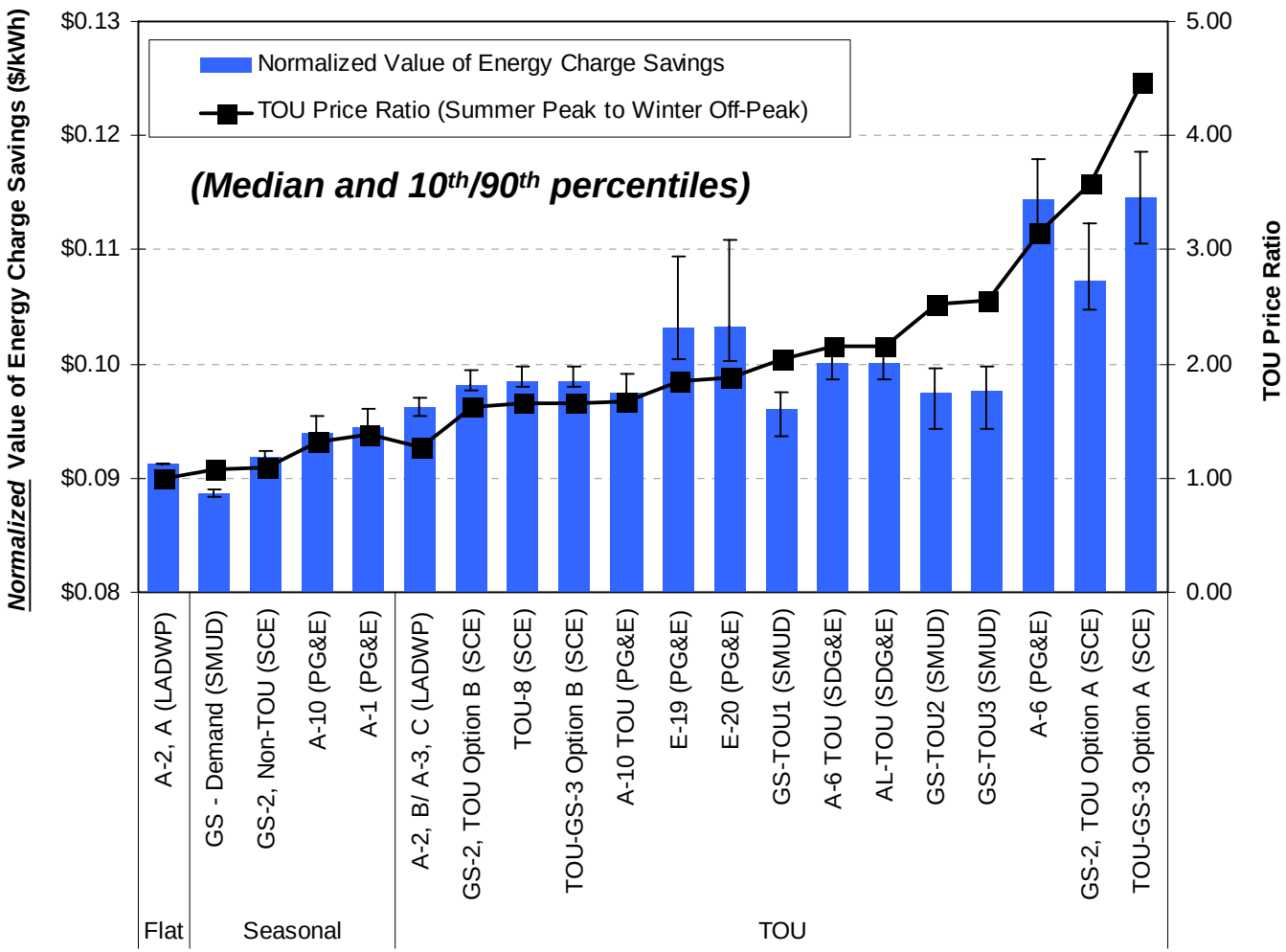
(Median and 10th/90th percentiles)





- Customers with afternoon peaks can generate significant demand charge savings across all types of demand charges
- Customers with inverted or flat load profiles can earn modest demand charge savings if TOD-based demand charges are used

TOU Energy Rates with a Large Peak to Off-Peak Price Spread Offer More Value

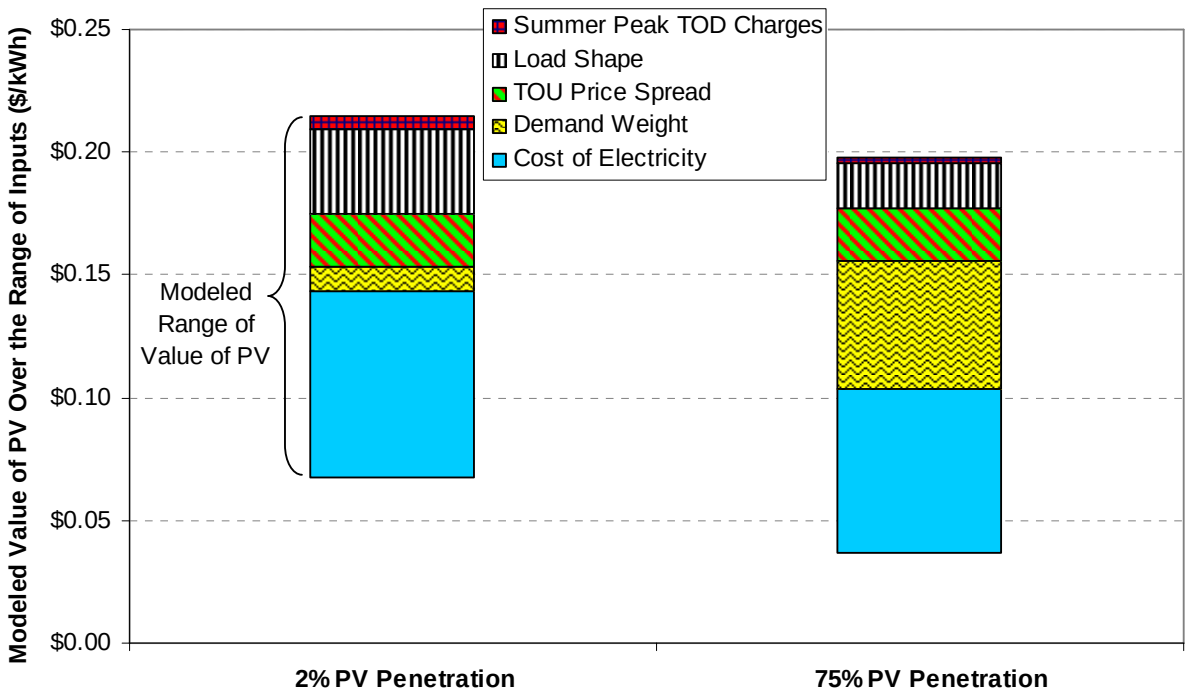


- TOU energy rates heavily weighted toward the summer peak period provide ~20% greater savings on energy charges than flat rates
- This effect (~$0.02/kWh) is relatively small compared to the overall variation in the value of PV across rates

Summary: What Drives Differences in the Value of PV?

We fit the value of PV for each customer/rate combination to a multiple linear regression model, to compare the impact of each of the issues examined

- Figure disaggregates overall variation in the value of PV into individual factors
- The average cost of electricity of each rate has the largest impact
- Depending on PV penetration, the second most-important factor is either load shape or demand weight



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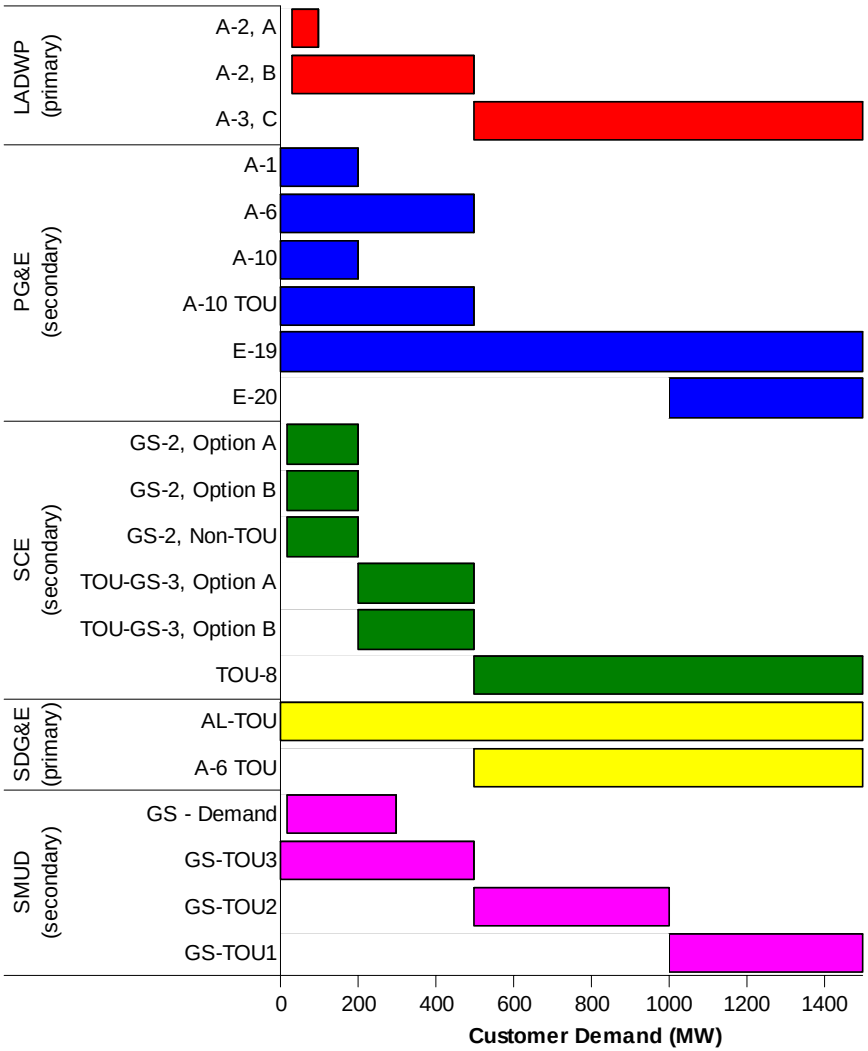
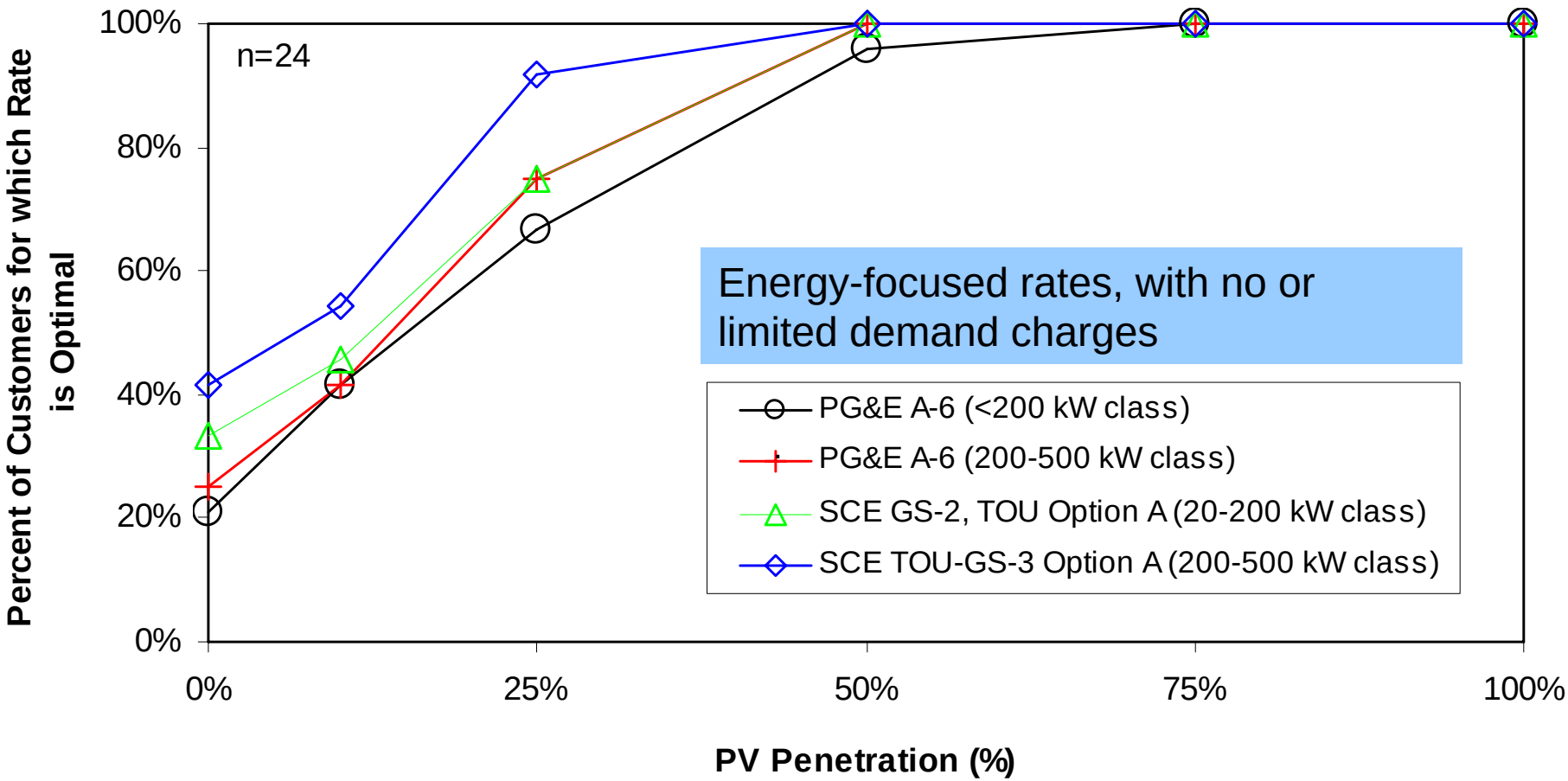
Rate Switching Analysis



- Multiple rate options are available within many customer size classes (see figure)
- Within each class, we determine which rate is least cost for each of the 24 load/PV production dataset pairs, both before and after the PV system

Energy-Focused Rates Are Advantageous at Higher PV Penetration Levels

At low levels of PV penetration, customer load characteristics determine the optimal rate; at high levels of PV penetration, nearly all customers would switch to a rate with minimal demand charges

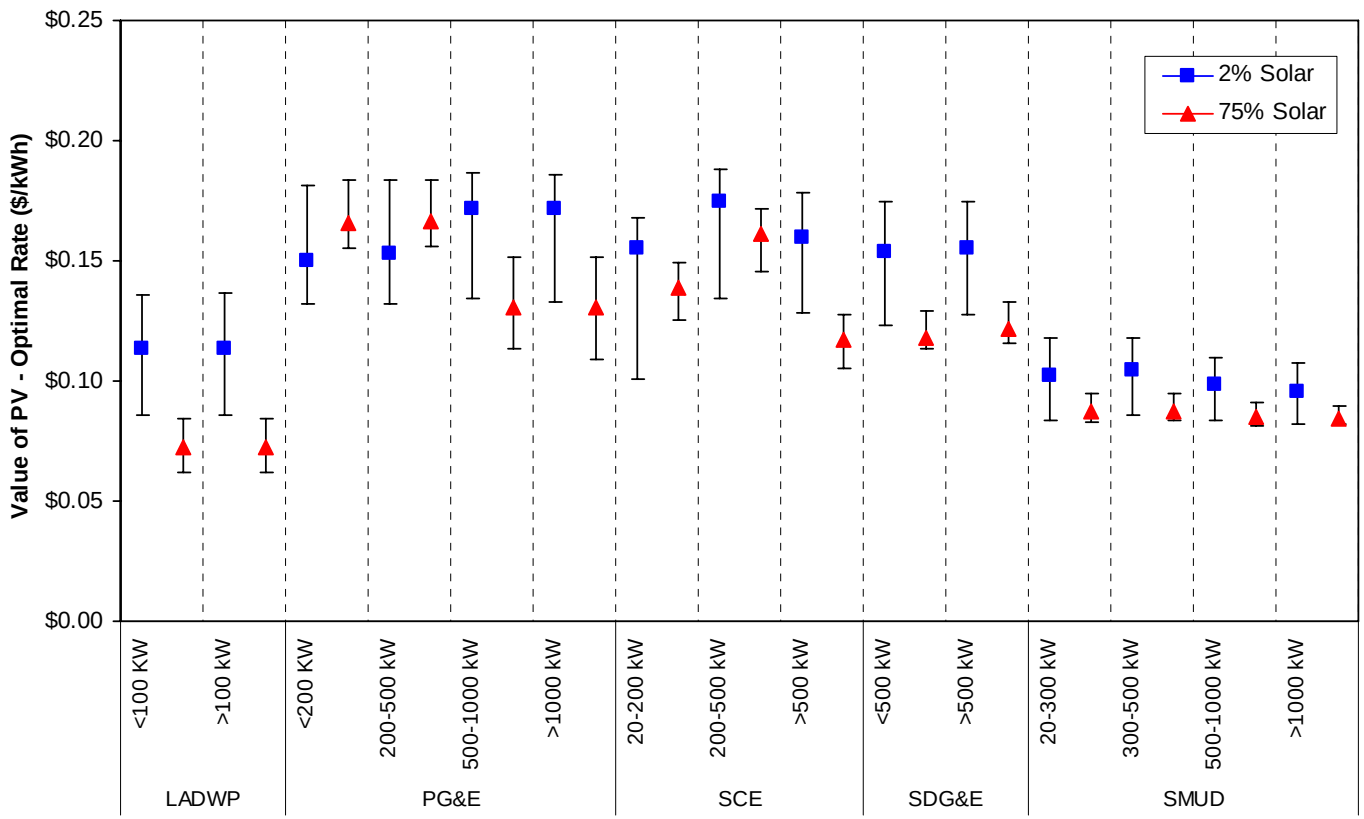


The Rate-Reduction Value of PV with Rate Switching

We calculate the Value of PV for each "rate class" when customers choose the least cost rate option before and after PV

- The figure arguably represents the most accurate picture of the value of PV for commercial PV systems in CA
- Variation across rate classes is somewhat smaller than across individual rates, but still significant

(Median and 10th/90th percentiles)



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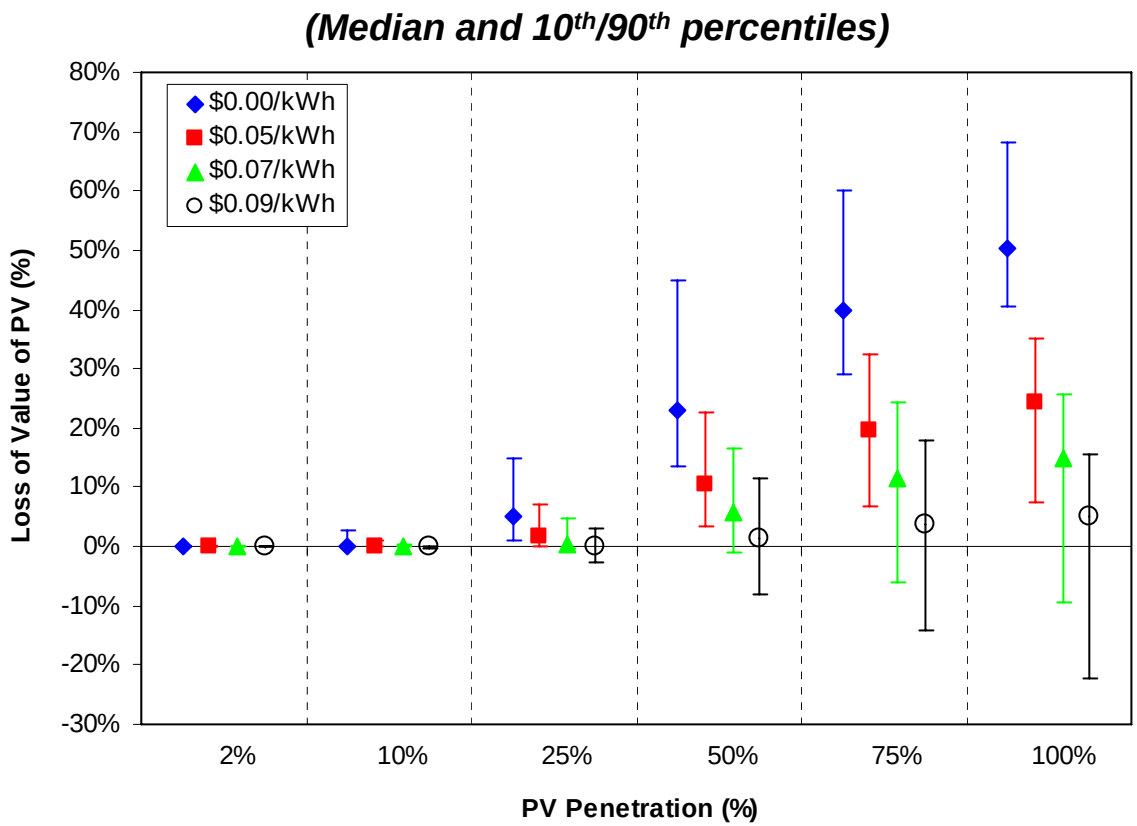
Assessing the Value of Net Metering

- **We calculate the loss in the value of bill savings for each customer/rate combination, if net metering were replaced with an alternative compensation structure:**
  - In each 15-minute interval, customer is compensated for PV output *in excess of load* at a flat "sell back" rate
  - No difference from net metering in intervals when PV output is less than customer demand
  - Estimate reduction in bill savings at "sell back" rates ranging from $0.00/kWh to $0.09/kWh
- **Note that this is not the same as a "feed-in" tariff, which would be considerably more straightforward to analyze**

The Loss of Net Metering Could Greatly Reduce the Value of PV for Large PV Systems

The figure shows the percentage reduction in bill savings if net metering were eliminated, in terms of the median and percentile values across all combinations of customers and rates

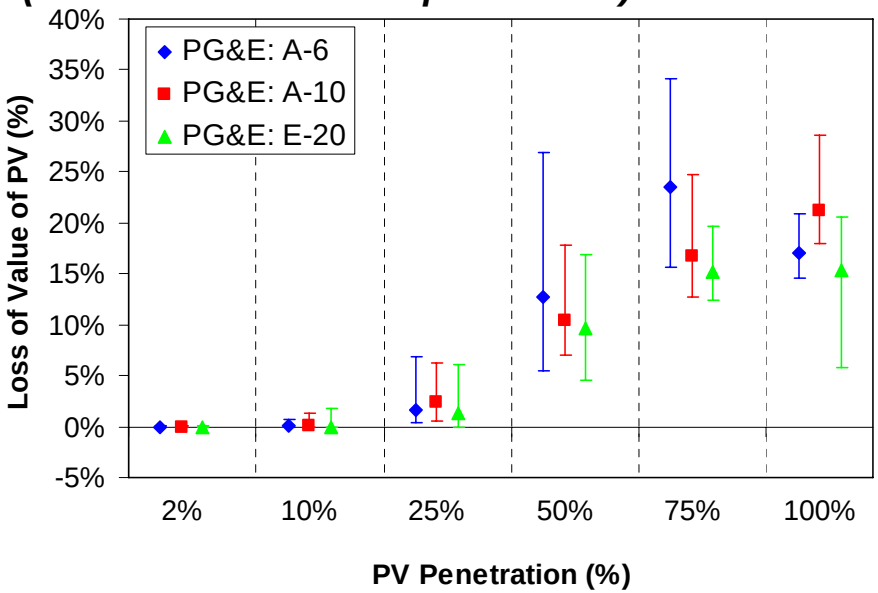
- At PV penetration of 25% or less, net metering provides little value compared to the alternative considered
- At higher PV penetration, net metering is much more valuable, but is highly sensitive to the sell-back price

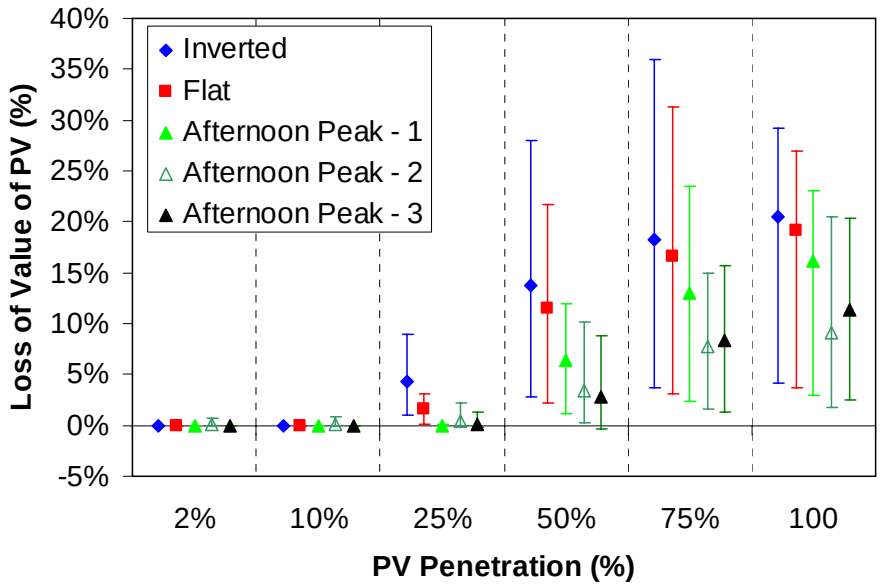


The Impact of the Loss Net Metering Depends on Rate Structure and Load Shape

Graphs assume excess is sold to utility at $0.07/kWh

(Median and 10th/90th percentiles)





The potential economic loss from eliminating net metering is greatest for customers on energy-focused rates, like PG&E's A-6 rate

Customers with inverted or flat load profiles depend more on net metering than customers with afternoon peak load shapes

Key Findings on Rate Design

- Commercial PV systems can generate significant demand charge savings, depending on...
  - **PV penetration level**: the value of demand charge reductions declines dramatically with increasing PV penetration
  - **Customer load shape**: customers with loads that peak in the afternoon earn much greater demand charge savings than those with flat or inverted load shapes
  - **Demand charge design**: TOD-based demand charges are more favorable to PV under a broad range of customer load shapes than those based on monthly or annual peak customer demand
- TOU-based energy charges with a high spread between peak and off-peak prices offer greater value (~20% on average) than rates with seasonal or flat energy charges
- Differences in temporal PV production profiles have a modest impact on PV value

Key Implications for Policymakers

- **Rate design is fundamental to the economics of commercial PV**
- **TOU-based, energy-focused rates can provide substantial value to PV**
- **Offering customers a variety of rate options would be of value to PV**
- **Eliminating net metering can significantly degrade the economics of PV systems that serve a large percentage of building load**

Future Extensions of Analysis

- Can publicly available, hourly simulated PV production data replace actual 15-minute interval PV production data and still accurately estimate demand charge savings?
- What are the impacts of rate structures available in other states? What effect do standby and backup charges have on the value of commercial PV?
- Based on actual PV system data, what is the impact of retail rate structures on the economics of *residential* PV?
- What is the impact of customer-sited PV on the grid and how well are the benefits of PV reflected in retail rate structures?

For more information...

Download the report:

http://eetd.lbl.gov/ea/ems/re-pubs.html

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