Exploring Demand Charge Savings from Commercial Solar

Naïm Darghouth, Galen Barbose, Andrew Mills, and Ryan Wiser, Lawrence Berkeley National Laboratory
Pieter Gagnon and Lori Bird, National Renewable Energy Laboratory

Overview

Commercial retail electricity rates commonly include a demand charge component, based on some measure of the customer's peak demand. Customer-sited solar PV can potentially reduce demand charges, but the magnitude of these savings can be difficult to predict, given variations in demand charge designs, customer loads, and PV generation profiles. Moreover, depending on the circumstances, demand charges from solar may or may not align well with associated utility cost savings.

Lawrence Berkeley National Laboratory (Berkeley Lab) and the National Renewable Energy Laboratory (NREL) are collaborating in a series of studies to understand how solar PV can reduce demand charge levels for a variety of customer types and demand charges designs. Previous work focused on residential customers with solar. This study, instead, focuses on commercial customers and seeks to understand the extent and conditions under which rooftop can solar reduce commercial demand charges. To answer these questions, we simulate demand charge savings for a broad range of commercial customer types, demand charge designs, locations, and PV system characteristics. This particular analysis does not include storage, but a subsequent analysis in this series will evaluate demand charge savings for commercial customers with solar and storage.

Data and Methods

The analysis is based on 30-minute weather data spanning a 17-year historical period (1998-2014), sourced from the National Solar Radiation Database. Using those data, we simulate building loads for fifteen commercial customer groups using the Department of Energy's Energy+ Commercial Reference Building Models. The simulations are performed across 15 U.S. cities. Using the same weather data, we simulate rooftop PV generation using NREL's System Advisor Model. These simulations are performed for the same set of U.S. cities and across multiple PV system sizes (ranging from 10% to 100% of each customer's annual energy consumption) and orientations (south, southwest, west, and flat). This set of simulations yields 9,000 pairs of building load and PV generation data, with each pair based on the same location and time period.

For each pair of load/PV data, we estimate monthly demand charge savings from solar, by comparing demand charges with and without solar, under numerous demand charge designs. Under the "basic" non-coincident demand charge, the customer is charged for its maximum demand during any 30-minute interval over the course of each month. We also estimate demand charge savings under designs with seasonally varying demand charges; with ratchets; with averaging intervals ranging from 30 minutes to 2 hours; and with charges based on the customer's maximum demand during various specified peak period windows, beginning and ending at various times between 8 am and 8 pm.

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Key Findings

We compare demand charge savings across the various permutations of load/PV data and demand charge designs in terms of the average reduction in monthly demand charges over the entire 17-year analysis period. The principal metric used in the analysis is the percentage reduction in average billing demand, relative to the customer's billing demand without PV. Though not included in this executive summary, we also present a subset of the results using a second metric in the full briefing's appendix. This metric is termed the *demand charge capacity credit*, and serves as a point of comparison to the capacity credit used to estimate avoided utility system costs. In addition to comparing average demand charge reductions, we also compare *variability* in monthly demand charge savings across demand charge designs, though those results are included only in the full briefing.

Under a basic, non-coincident demand charge design, commercial customers generally achieve low reductions in demand charges from solar. As shown in Figure 1 (the left-most bar segment), rooftop solar reduces demand charges by just 7% in the median case and by less than 15% in about 90% of all cases when based on a basic non-coincident demand charge, for customers with PV systems that generate 50% of their annual load. Demand charge savings for many customers are relatively low under this design, because most commercial customers load profiles that do not align well with PV generation. That said, some commercial customers may be able to generate more-significant savings under a non-coincident demand charge design (e.g., a 20% reduction in demand charges or more). This contrasts with the findings from our earlier analysis of demand charge savings from residential solar, which found lower savings overall and much less variability across customers, when based on a non-coincident design.

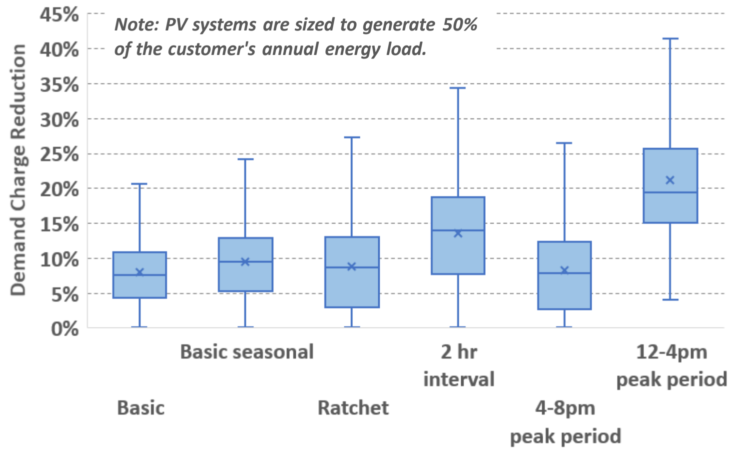

Figure 1. Distribution in average billing demand reduction for various illustrative demand charge designs, over all combinations of commercial customers included in the analysis

Notes: Each box-and-whiskers plot shows the distribution in the average monthly reduction in billing demand, across 900 combinations of simulated load generation and PV generation profiles for customers with PV systems that generate 50% of their annual load. 'x' = mean; shaded box = 25th-75th percentile range; middle line = median; whiskers are maximum and minimum excluding outliers.

Demand charge savings may be significantly greater when based on pre-defined peak periods and on longer time averaging intervals. For example, if based on the customer's maximum demand during a 12-4 pm peak period, commercial solar reduces demand charges by 19% in the median case, and by 40% or more in some cases, as illustrated in Figure 1. Under demand charge designs with peak periods that end later in the day, for example a 4-8 pm peak period, demand charge savings from solar are significantly lower. This is because many customers' peak demand tends to occur at the end of the peak period window, at which point solar output is lower. Demand charge savings from commercial solar are also sensitive to the length of the averaging interval used to compute billing demand. Averaging load over longer periods of time (such as 2 hours, shown in Figure 1) can smooth out variability in PV generation due to intermittent cloud cover, as well as better align load and PV generation when peak load occurs later in the daytime; both of these dynamics can lead to higher demand charge savings. The impacts of averaging interval length on demand charge savings are particularly salient under demand charge designs based on afternoon peak periods (see p. 29 of the full briefing).

Other demand charge design elements generally have less significance for bill savings from solar. As shown in Figure 1, seasonally varying demand charges and ratchets do not significantly impact demand charge reductions from solar, when applied to a basic non-coincident peak demand charge. Seasonal demand charges, where demand charges are higher in summer months, tend to provide a small boost in demand charge reductions from solar. Though not shown here, the relative effect of the seasonal element on the demand charge is similar for the basic demand charge design and that with a 12-4 pm peak (see p. 30 of the full briefing). Ratchets, which create a minimum billing demand based on peak demand in the past year, have a small positive or negative effect on demand charge savings, depending on the commercial customer type and the underlying demand charge design (i.e. see p. 31 of the full briefing).

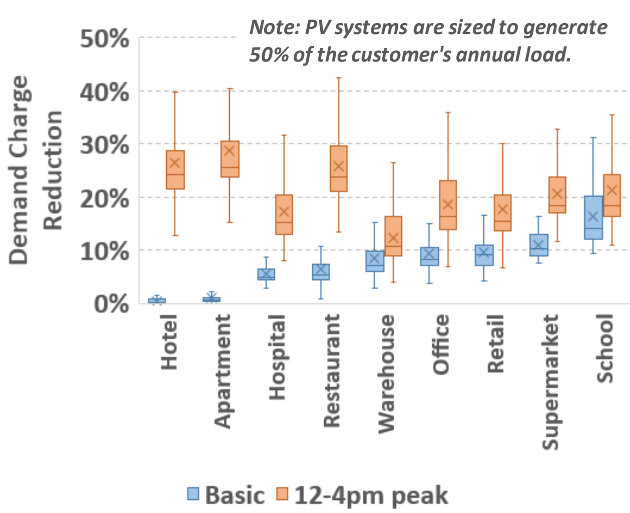

Figure 2. Distribution in average billing demand reduction for various commercial customer groups for the non-coincident and the 12-4 pm peak demand charge designs

Demand charge reductions from solar are heavily dependent on building type. As observed in Figure 2, demand charge reductions can vary significantly from one commercial building group to another, though those comparisons differ depending on demand charge design. For the basic, non-coincident demand charge (blue bars), demand reductions from solar are generally highest for schools and supermarkets, whose load profiles better correspond to PV generation and achieve a mean non-coincident demand charge reduction of 18% for customers with PV systems that generate 50% of their annual load. At the other end of the distribution are apartments and hotels, whose loads tend to peak in the late afternoon and evening, and therefore achieve zero demand charge savings in almost all cases under a non-coincident demand charge design. For most building types, non-coincident demand reductions are low (i.e., 5-10% for PV systems that generate 50% of annual customer load). The ability for PV to reduce non-coincident demand is limited by poor coincidence between load and PV generation profiles for most commercial customers, as well as by cloudiness, which may coincide with peak load. For the 12-4 pm peak period demand charge design, there are also differences in demand charge reductions by commercial building type, but these are less significant than for the non-coincident demand reductions, given the lower variability in load profiles during the 12-4 pm window.

Daily load variability and load factors can help a potential solar customer understand the general magnitude of demand charge savings, particularly if their load shapes do not conform to the general commercial customer types considered in this analysis. Our findings show that customers with higher load factors are more likely to have lower demand charge savings from solar as do customers with more variable daily peak loads.

Demand charge savings increase with PV system size, but with diminishing returns. In contrast to volumetric energy charges, demand charge savings do not scale directly in proportion to PV system size. For example, under a basic, non-coincident demand charge design, a school in Phoenix with a PV system sized to meet just 20% of its annual energy needs reduces demand charges by 16% in the median case, but if sized to meet 100% of its annual energy needs reduces demand charges by only 29%. This occurs for several reasons: larger systems push peak demand to later in the day; larger systems push peak demand to cloudy days; and, under peak period demand charge designs, demand charges in some months can be eliminated, in which case further increases in system size yield no additional savings. For the basic, non-coincident demand charge design, the degree to which there are diminishing returns with increasing PV system size depends on the commercial customer type. Restaurants, for example, quickly reach their maximum non-coincident demand charge reductions with relatively small PV systems, whereas demand charge reductions continue to increase with increasing PV system sizes for schools, as shown for Phoenix in Figure 3.

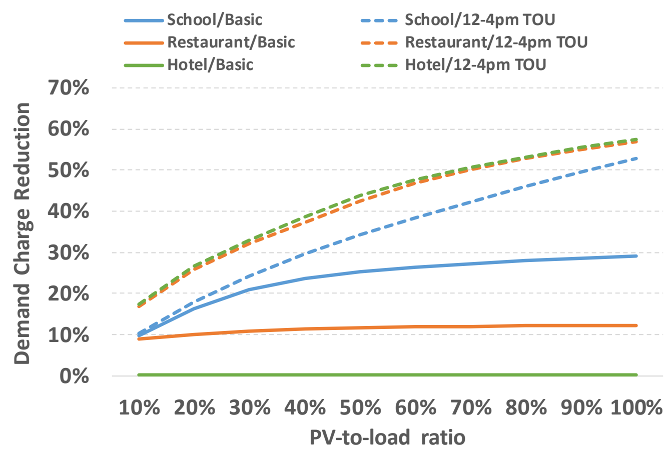

Figure 3. Demand charge reductions with increasing PV system size for the basic and the 12-4 pm peak demand charge designs for three commercial building types in Phoenix

Orienting PV panels westward yields, at most, only slight increases in demand charge savings. Southwest- and west-facing panels peak later in the day, coinciding better with load than flat or south-facing panels. The increase in the demand charge savings occur across commercial customer types and demand charge designs but are generally quite modest, as shown in Figure 4. For example, for a school in Phoenix, the average demand charge reduction under a 12-4 pm peak demand charge rises from 31% for a south-facing system to 34% for a southwest and west-facing system. The increase in the demand charge reduction moving from flat to southwest and west-facing PV panels is roughly similar across customer types and never more than a few percentage points.

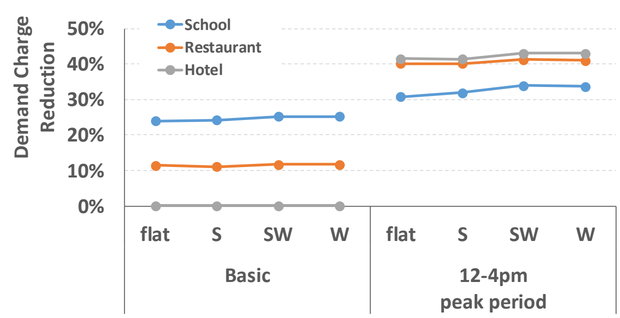

Figure 4. Change in demand charge reduction across PV panel orientations

Note: The figure shows the mean demand charge reductions for PV customers in Phoenix for a single PV system size kept constant for all orientations (50% PV-to-load ratio for a South facing system), to eliminate variability due to PV system size.

Conclusions

This analysis focuses on demand charge savings from solar for commercial customers. Previous work considered residential customers, and upcoming work will consider the synergies between PV and storage in reducing demand charges.

There are a few limitations in the methodology and scope of this work. First, it is based on 30-minute interval data, whereas existing demand charges are often based on 15-minute averaging intervals; as our results show, longer averaging intervals generally result in larger demand charge savings. Second, the simulated building loads used in this analysis do not capture all sources of variability in customer loads—e.g., variations in occupancy patterns or all possible variations in end-use equipment—nor do they account for possible load shifting behavior that might occur as a result of demand charges. Our analysis considers PV-to-load ratios up to 100% (i.e. PV systems that generate 100% of annual load), though available roof-space for many commercial buildings will tend to limit PV system size to much smaller PV-to-load ratios. Finally, although the analysis encompasses a wide variety of demand charge designs, not all possible demand charge rate structures are considered; for example, we did not evaluate tiered demand charge rates, or demand charges based on peak demand averaged over multiple days.

Notwithstanding the limitations above, the findings presented here support several conclusions, with implications for ongoing rate reform efforts:

- **The widespread use of demand charges for commercial customers may tend to direct solar deployment towards particular business types and likely constrains overall growth.** In particular, non-coincident demand charges could have a limiting effect on commercial deployment overall, given that most commercial customers can generally expect small demand charge reductions from PV systems. The customer economics of PV are the least attractive for commercial customers with zero demand charge reductions, such as hotels or apartment buildings. The higher demand charge reductions for other customer types are likely to direct commercial PV deployment to those, whether it be schools, offices, or other customers with late afternoon- or evening-peaking loads. Deployment patterns could be spread more evenly across commercial customer types with peak window demand charges, which tends to reduce differences in demand charge reductions among customer types.
- **Some demand charge designs are clearly better than others for commercial customers with solar.** Although a few customer types, such as schools or offices, can have more significant demand charge savings from solar under the basic, non-coincident demand charge design, *all* customers have higher demand charge savings from solar under other designs such as the 12-4 pm peak window demand charge design. Such demand charge designs make demand charge savings more predictable for commercial customers as the savings do not deviate as much from one customer type to the next. This also has implications for commercial customers who do not have regular load shapes from one month to the next, as afternoon peak demand charge designs lead to less variable demand charge savings.
- **Demand charges incentivize commercial customers to install smaller PV systems.** Our findings show that larger PV systems do not generate proportionally larger demand charge reductions, indicating diminishing returns to scale. This effect is starkest with the basic, non-coincident demand charge, but is also observed with peak window demand charge designs. This suggests that smaller PV systems can be more effective at reducing demand charges in terms of bill savings per kW of solar installed.

- **Demand charges may not always align well with utility cost savings from solar.** Demand charges are often advanced on the basis that they better align customer bills with cost causation. Although this study does not directly compare demand charge savings to utility cost savings, and therefore cannot comprehensively assess their alignment, the findings shown here suggest several specific situations where demand charges are not likely to correspond well to utility cost savings from commercial solar. First, given that the system-wide value of a PV system is largely constant regardless of its host building, the wide variation in demand charge reductions from solar suggests that demand charges may not be effective at communicating the capacity value of PV to commercial customers. Second, at the bulk power system level, solar is generally recognized to provide some capacity value; for example, for electric systems with relatively low overall solar penetration, solar may have a capacity credit of 30-70%. As the preceding results show, the demand charge capacity credit received by commercial solar customers under a basic, non-coincident demand charge design is generally much less than that amount, in most cases under 10% and in some cases zero. Demand charges that are intended to recover bulk power system capital costs would therefore tend to under-compensate solar customers for the utility cost savings they provide, at least at low system-level solar penetrations. Finally, as the results presented here show, demand charge savings from solar exhibit diminishing returns to scale. There is little economic rationale for this relationship: though utility cost savings would be expected to decline with overall bulk power system and distribution system penetrations of solar, that relationship would not be expected to hold for individual PV systems. Instead, to the extent that individual commercial rooftop solar provides capacity value to the utility, that value would be expected to scale with the size of the system, and a well-aligned compensation mechanism would mirror that structure.
- **In other scenarios demand charge savings from commercial solar may better align with utility cost savings.** With the basic, non-coincident demand charge design, alignment may be good for a *subset* of commercial customers with peak loads that correspond to the bulk power system or distribution system peak times, depending on which costs the demand charge is designed to recover. Alternatively, there would be good alignment for demand charges defined with a peak period that mirrors that of the bulk power system, if the demand charge is designed to recover costs at the bulk power system level, or that of the distribution system peak, if the demand charge is instead meant to recover distribution capacity costs.

For More Information

Download the full briefing, published in slide-deck form

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Contact the authors

Naïm Darghouth: (510) 486-4570, ndargouth@lbl.gov
Galen Barbose: (510) 495-2593, glbarbose@lbl.gov

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