How to Estimate Demand Charge Savings from PV on Commercial Buildings

What are demand charges?

Demand charges are typically part of a commercial electricity customer's electric bill. These charges are designed to recuperate costs associated with the infrastructure needed to generate and distribute power to the customer, such as power plants and transmission lines. To put this in context, a typical commercial electricity tariff has three components:

- Demand charge: A charge for the maximum rate at which you consumed electricity during the month, measured in kilowatts (kW).
- Customer charge: A fixed dollar amount per month charge. These are designed to capture administrative and miscellaneous costs that do not vary significantly by usage levels.
- Energy charge: A charge for the total amount of electricity that you consumed during the month, typically measured in kilowatt-hours (kWh). This charge is designed to recuperate costs such as fuel and operating and maintenance costs, which are strongly correlated with energy consumption.

As an example, let us consider a hypothetical office building for the month of April. Imagine that the building consumed power at a constant rate of 100 kW, but it also had a 50 kW air conditioning unit turned on for a single hour during the month. Because April has 720 hours, the total energy consumption of the office is 100 kW × 720 hours + 50 kW × 1 hour = 72,050 kWh. The building's demand peaked when the air conditioner was running; however, the 50 kW on top of the 100 kW of miscellaneous loads leads to a total peak demand of 150 kW.

Utilities' total revenue from the sale of electricity to the entire commercial sector in the United States is composed of approximately 3% from customer charges, 25% from demand charges, and 72% from energy charges.[1] Those magnitudes vary moderately by region and significantly by customer. Demand charges that exceed 50% of a customer's monthly electric bill are common.

Can an onsite photovoltaic system reduce demand charges?

A solar photovoltaic (PV) system can reduce demand charges if the solar generation occurs at the same time as the host building's peak demand. Figure 1 shows the impact of PV on demand charges is shown for a simulated hotel and school. As shown in the left panel, the hotel's peak demand occurs in the evening after the sun is down, so a PV system would not reduce the hotel's peak demand and the hotel would not reap

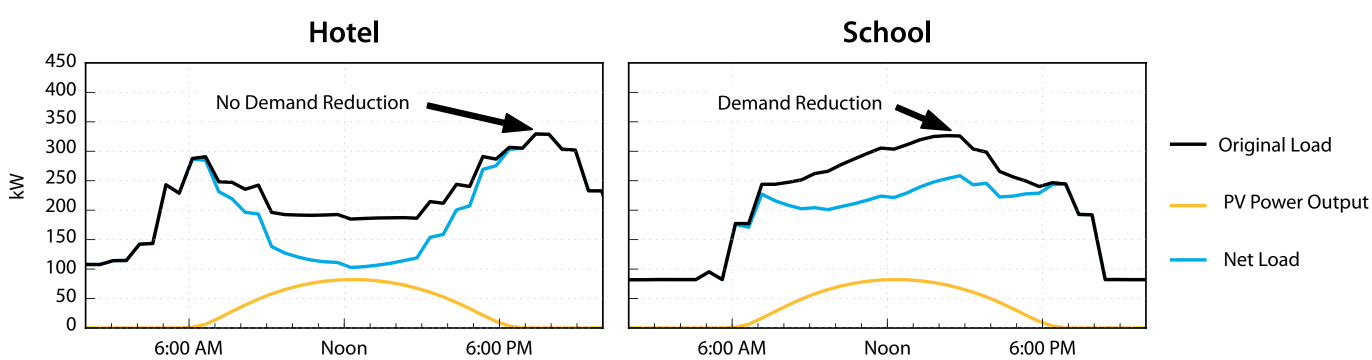

Figure 1. Simulated reduction in peak demand from PV on a hotel and school

[1] Revenue estimates are derived from a curated set of retail electricity tariffs, available in the Utility Rate Database (*http://en.openei.org/wiki/Utility_Rate_Database*), which were quality-checked for this analysis. Bill calculations were performed using approximately 3,000 representative commercial customers that are part of NREL's dGen model (*http://www.nrel.gov/analysis/dgen/*).

any demand charge savings from PV. In contrast, the school's original load peaks in the afternoon when the PV system would be near peak output. In this case, the school would be able to capture substantial demand charge savings from the installation of PV.

In general, buildings whose electricity demand is highest during the day—often schools and office buildings—have the greatest likelihood of seeing demand charge savings from PV. Buildings with evening peak demand, such as hotels and midrise apartments, often see little to no demand charge savings. In addition, there are diminishing returns on demand charge savings from PV—a sufficiently large system can reduce midday electricity demand to the point where peak demand occurs during the evening, when PV cannot capture any additional savings.

How can I estimate potential demand charge savings from a PV system?

It is impossible to predict with absolute certainty how much a PV system will influence a building's demand charges, but it is possible to estimate the range of potential savings. With hourly electricity consumption data and weather data that correspond to the same date range and location, you can use NREL's *System Advisor Model* to evaluate potential savings.[2]

Even without this hourly data, you can estimate a potential range of demand charge savings using the following procedure and look-up graphs in Figure 2. These graphs characterize the relationship between PV and a reduction in peak demand based on simulations of 16 representative commercial buildings in 16 different climate zones using 17 years' worth of historical weather data.[3]

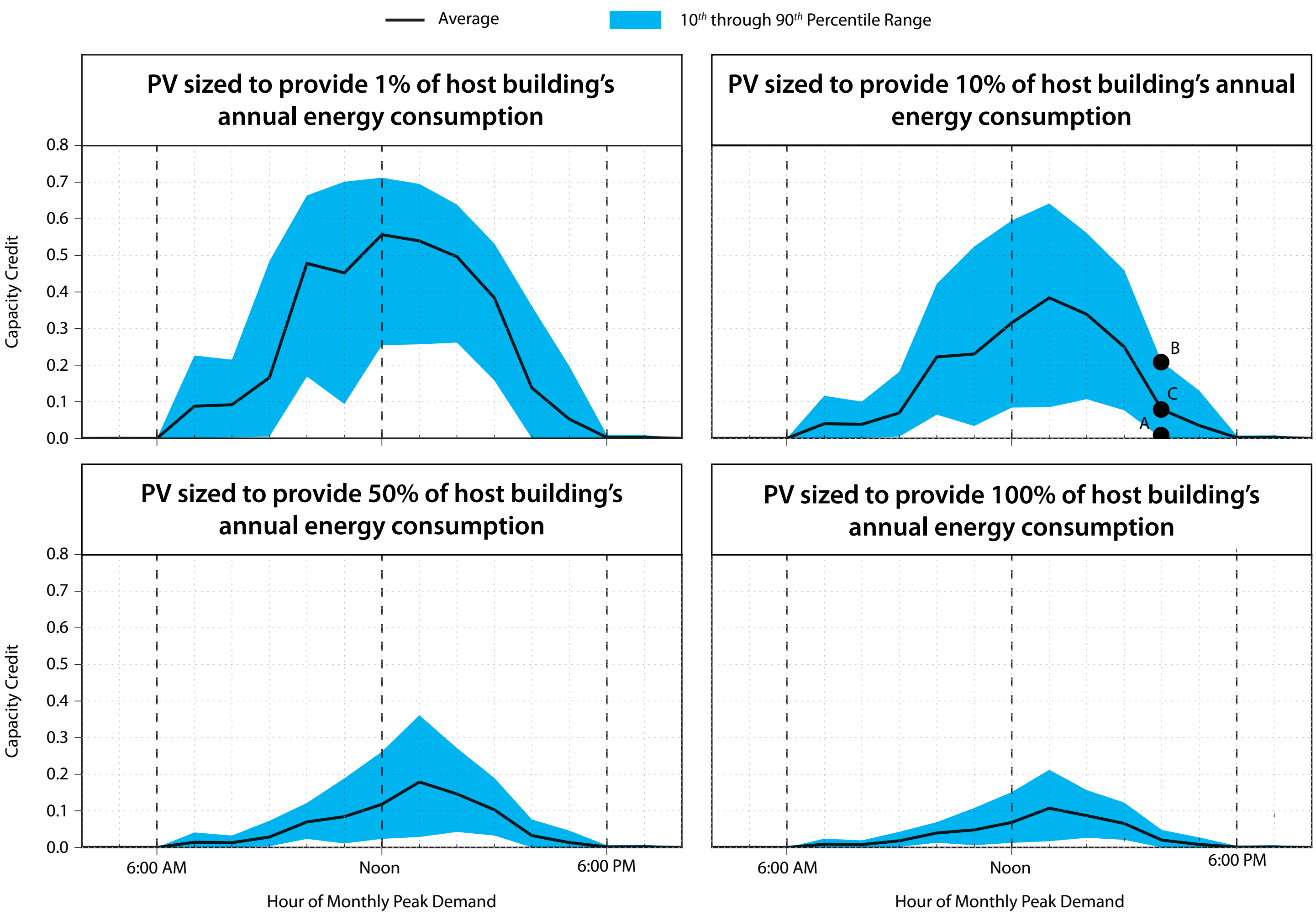

Figure 2. Look-up figures for PV capacity credits for four PV sizes

[2] See *https://sam.nrel.gov*.

[3] The procedure and figures given here were derived from Darghouth et al. (2017a). For a deeper dive into the interaction of PV and demand charges, see Darghouth et al. (2017a) and its equivalent for the residential sector, Darghouth et al. (2017b).

[4] See *http://pvwatts.nrel.gov/*.

The Process for Estimating a Range of Demand Charge Savings

1. Estimate the annual energy production of the PV system you are considering, in kWh per year. If you are working with a developer, they should be able to provide this value for you. Alternatively, you can use NREL's *PVWatts Calculator* to estimate PV production.[4] Lastly, you can roughly estimate annual production by multiplying the size of the system in kilowatts by 1,410 kWh/kW.
2. Use electric bills from the previous year to estimate your building's annual energy consumption.
3. Calculate the PV system's energy production as a percentage of your building's annual energy consumption:

$$\text{PV Production \%} = \frac{\text{Annual PV Production (kWh)}}{\text{Annual Electricity Consumption}} \times 100\%$$

4. Identify which of the panels in Figure 2 is closest to the PV production percentage calculated in step 3. For each month of the year, use the panel to identify the range of capacity credits for the hour that your building's electric demand peaks during that month. If your PV production percentage is sufficiently different from any one of the panels, it would be more accurate to interpolate between the values of two of them.
5. Use the following equation to estimate the demand charge savings for each month. Solve the equation three times – once for the lower 10th percentile capacity credit from step 4, once for the average capacity credit, and once for the upper 90th percentile. Perform this for each month of the year, and add the monthly values to arrive at an estimate of the potential range of demand charge savings.

$$\text{Monthly Demand Charge Savings (\$)} = \text{Monthly Demand Charge Rate (\$/kW)} * \text{PV Size (kW)} * \text{Capacity Credit}$$

How to Use the Process: An Example

Imagine you own a building that reaches its peak demand around 4 p.m. in July and consumed 300,000 kWh of electricity in the preceding year. You are considering a 20-kW PV system, and the demand charge for the month is $10/kW. You can estimate the PV production as 20 kW * 1410 kWh/kW = 28,200 kWh. You can then estimate the PV production percentage as 28,200 kWh / 300,000 kWh = 9.4%. Looking at Figure 2, the upper right panel most closely resembles the fraction of electricity consumption offset by the PV system. The range of capacity credits for the hour that your building peaks are labeled as A, B, and C in Figure 2—zero for the lower end of the range, 0.20 for the higher end, and 0.08 on average. Putting these capacity credits in the equation in step 5 gives a range of potential savings for this month: $0 to $40, with the average building saving $16. Repeat this for each month to get an estimate of the potential range of total annual demand charge savings from PV.

Keep in mind that these are just estimates based on simulations with only a small amount of input from your specific situation. The actual demand charge savings can vary based on daylight hours in your region and the patterns in both energy consumption and PV production. This method of estimation is also based on the simplest type of demand charges based on a building's monthly maximum demand, but other forms of complexity in demand charge design may affect actual savings. These are reasonable first approximations, but more detailed analysis could be beneficial if demand charges play a pivotal role in your decision of whether to invest.

Table 1. Variations in Demand Charge Designs

Demand Charge Style and Description	Influence on PV's Demand Charge Savings
Time-of-use: A window of time is specified (e.g., 5 p.m. to 9 p.m.), and demand charges are calculated using a customer's maximum demand during that window.	Time-of-use windows can significantly affect demand charge savings. Windows that extend outside of daylight hours tend to decrease savings, whereas windows that are entirely within daylight hours tend to increase savings.
Seasonal: Instead of a constant $/kW for each month of the year, values for seasons differ. Often, the summer charges are higher than winter charges.	PV production is typically greatest during summer months; therefore, demand charge savings from PV are often slightly higher for tariffs that have seasonal components that are higher during the summer.
Declining or inclining tiers: Instead of a single $/kW rate, there can be different rates for different tiers of demand. For example, a declining tier might charge $10/kW for the first 500 kW but only $5/kW for any amount beyond that. Declining tiers are more common for commercial customers in the United States.	Declining tiers typically reduce PV savings from demand charges because the PV reduces demand from the top tiers first, which are charged at a lower rate. Inclining tiers typically increase PV savings.
15, 30, or 60 minute 'averaging interval': Demand charge levels are rarely calculated on instantaneous peak demands but instead average demand over a window of time. The most common windows are 15, 30, and 60 minutes.	Temporary dips in PV production (e.g., from a cloud passing overhead) can set a month's demand charge; therefore, demand charge savings from PV are typically greater with longer windows because the longer time averages out the dip in production.
Ratchets: Some tariffs set demand charges as either the current month's highest demand level or a fraction of some historical maximum. For example, a tariff may say that the demand charge is $10/kW of "billing demand," where "billing demand" is either the current month's maximum demand or 70% of the customer's maximum demand during the summer months, whichever is higher.	Ratchets can have a wide range of impacts on demand charge savings.

Demand Charge Design Variations

Demand charges can vary by time of day, by season, or can be based on more complex calculations of the building's demand. The process outlined on the previous page uses the simplest demand charges—ones that are assessed based on a building's monthly maximum demand. Table 1 provides qualitative guidance on estimating demand charge savings from PV under more complicated designs.

If you are unfamiliar with what type of demand charge design applies to your building, you can use a recent electric bill to look up your tariff (e.g., "General Service 2") and then look up the description of this tariff on your utility's website. Note that some tariffs have more than one demand charge element (e.g., a flat component as well as a time-of-use component). The savings from these different elements can be evaluated separately and added together.

References and Further Reading

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