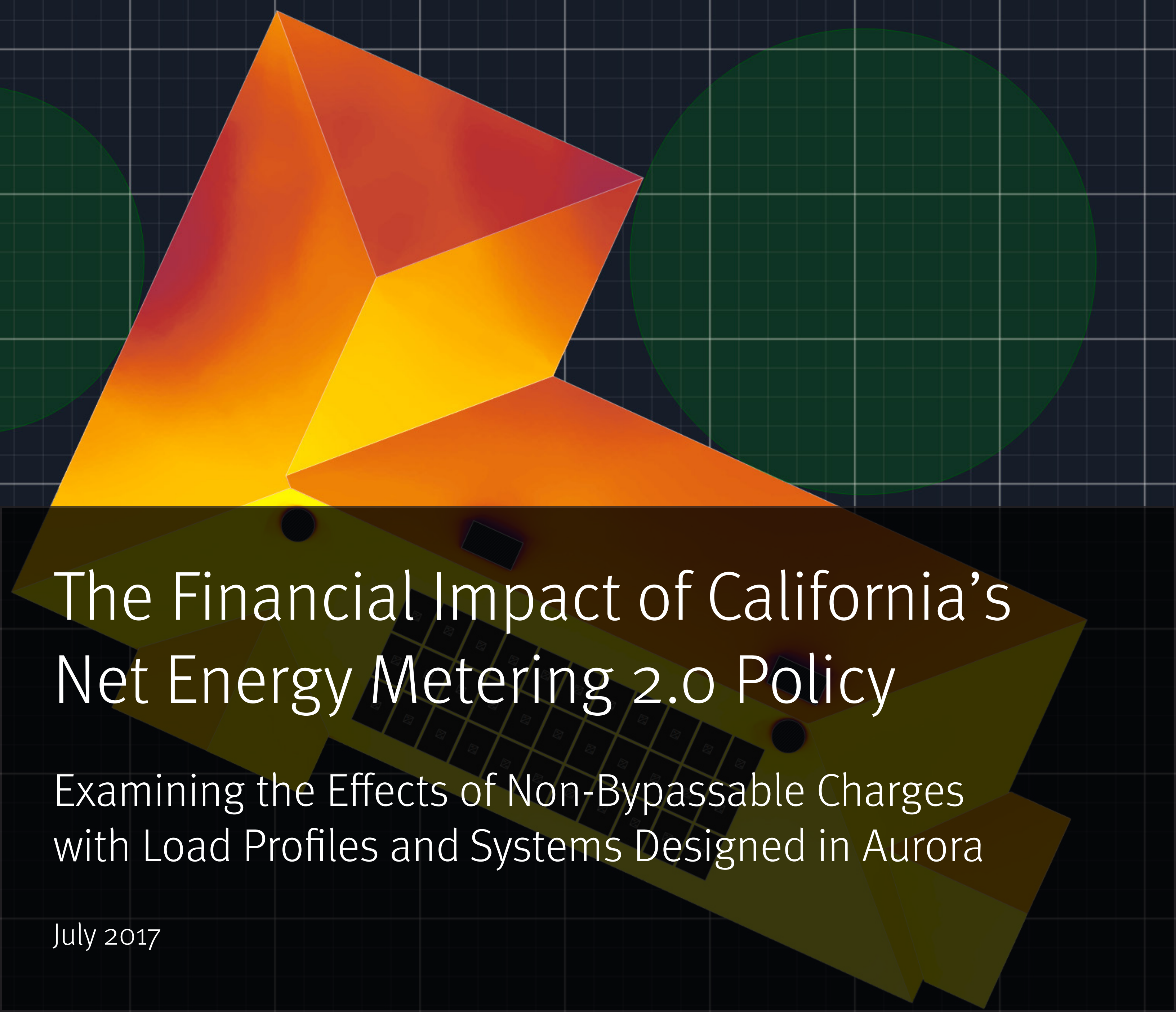

The Financial Impact of California's Net Energy Metering 2.0 Policy

Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora

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Aurora Solar Inc.

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aurora

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About Aurora

Aurora is the solar industry's leading platform for PV sales and system design. Aurora streamlines and automates the solar design process, empowering solar professionals to focus on what matters most – satisfying their customers. Over the past three years Aurora has developed several industry leading features, including bankable shade reports, automatic system design, detailed financial analysis, and customizable sales proposals. Aurora is used by solar installers across the U.S. and around the world, with over 12,000 installations designed in our software every week.

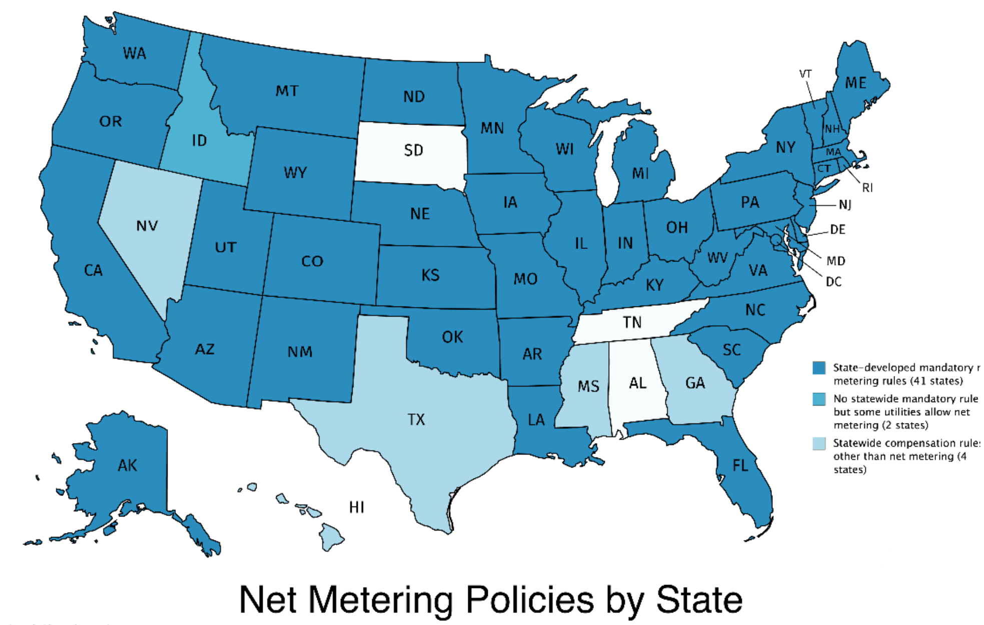
To learn more about Aurora, please visit https://www.aurorasolar.com/ or email hello@aurorasolar.com

Notice

Introduction

Net energy metering (NEM) is a policy where customers with renewable energy systems can earn credits for the energy they export to the grid. Energy is exported to the grid when the amount of energy produced by the PV system exceeds the customer's energy consumption at a given point in time. The credits can be used to purchase electricity from the utility at a different time. The classic example of this is a residential rooftop photovoltaic system. During the day, if the home produces more electricity than it consumes, the surplus of electricity is sent to the grid for credits. During the evening when the photovoltaic system is no longer producing any electricity, the accumulated credits can be used to purchase electricity directly from the utility.

In the U.S., NEM is the most common means of compensating producers of solar energy [1]. NEM was established by Senate bill 656 in 1995, and as of July 2016, 41 states have mandatory NEM policies.[1] According to GTM Research's Cory Honeyman, "The overwhelming majority of DG solar that has come online to date [in the U.S.] has come from projects taking advantage of net metering, not Feed-In Tariffs."



Source: Database of State Incentives for Renewable Energy

Why is the NEM policy changing?

In the original Net Energy Metering policy [2], each of California's utilities were required to create a NEM program for customers on a first-come-first-served basis until reaching a cap of 5% of aggregate consumer demand, after which NEM would be closed. The NEM Successor Tariff is the next version of NEM, and extends the cap to 7.5% of aggregate demand or until 2019. Generally referred to as NEM 2.0, the new policy addresses a few issues from the original NEM rules.

One criticism of the original NEM policy in California is that NEM customers were not paying a fair share towards certain public programs that are financed through a portion of the total electric rate, and several

[1] http://blog.aurorasolar.com/how-much-is-solar-energy-worth-understanding-solar-compensation-under-net-energy-metering-and-feed-in-tariffs/

companies as well as the three big Investor Owned Utilities (IOUs) argued that this was placing an unfair cost on non-solar customers. In addition, the increase of renewables on the grid has contributed to grid ramping issues in California's grid demand which have been growing worse over time [3]. This has led to a push by the California grid operator CAISO to make TOU rates the default for all customers [4, 5] and to recommend later peak TOU periods to help mitigate the ramping required as grid demand goes up and solar production falls in the afternoon.

What are the changes between NEM 1.0 and NEM 2.0?

To address the above issues, two major changes were implemented in the NEM Successor Tariff. First and most noteworthy is the addition of non-bypassable charges (NBCs), which add a $0.02 – $0.03/kWh reduction on the value of electricity exported to the grid and separates the non-bypassable component of the bill into a separate category that can not be offset by future energy credits. While studies [6, 7] have found that NEM has been an overall positive for the state of California, the CPUC determined in Decision 16-01-044 p.88 [8] that NBCs should be assessed on NEM customers to help maintain revenue for the programs, which are currently Nuclear Decommissioning, Public Programs, California Bond Charges and Competition Transition Charge. These are not a new component of the utility rate – they existed prior to the roll-out of NEM 2.0 – nor are they a charge specific to solar customers as all customers pay towards these programs as part of the electricity bill.

In addition, NEM 2.0 customers must enroll in a time-of-use (TOU) rate as part of CAISO's push towards grid stability and pay a small fee for solar interconnection. NEM 2.0 financial calculations have several more layers of complexity than before.

What are the implications of NEM 2.0 on the financial returns to solar and PV design practices?

The transition to NEM 2.0 has raised questions within the solar industry about the implications on the financial returns to solar, and on common solar PV design best-practices. While these questions are most pressing in California, where solar PV customers are already seeing the new rates affecting their bills, many regions across the country are also looking to California as they consider the successor to their current program. We found that the financial repercussions on residential solar installations of NEM 2.0 versus NEM 1.0 varied: while in most cases it did lead to lower returns to solar, this was very dependent on the characteristics of the design. We also found that under NEM 2.0 the optimal size design for a residential site was very different from that of under NEM 1.0.

A Detailed Look at the NEM Successor Tariff

The first step to understanding how NBCs are assessed is to look at the interplay between the consumption and production profiles of a house. Graphically, Figure 1 shows consumption in red and production in yellow with three distinct regions. Areas shaded red represent energy drawn from the grid, which we will call Gross Imports. Energy production from the PV array falls into two categories – some of which acts as an immediate offset to energy consumption, and some of which is sent out to the grid as Gross Exports. NBCs are assessed on net energy draws from the grid, in this case the Gross Imports. For the year, a household's accrued NBCs will simply be the sum of all gross imports multiplied by the prevailing NBC rate.

Next let's look at how NBCs accrue over the course of a day. Figure 2 shows the cumulative NEM 1.0 electric bill and a cumulative NEM 2.0 bill side-by-side over the course of one day; each has the same hypothetical rate schedule and consumption profile. For this example, the rate schedule used is a TOU rate with $0.20/kWh off-peak and $0.30/kWh on-peak from 3-8pm, and a NBC rate of $0.03/kWh[2].

[2] http://blog.aurorasolar.com/how-time-of-use-rates-work/

- Between midnight and 6am, the utility bill accumulates equally for both customers, although a small portion of the NEM 2.0 customer's bill is comprised of NBCs
- Around 7am, the sun comes up and begins to produce credits for excess production
- Throughout the day both customer's energy related charges are reduced to zero by 10am, after which excess credits are generated, but the NEM 2.0 customer's NBCs are never offset
- After 4pm, the production from the PV system wanes and the excess credits are used up
- At the end of the day, both customers still have excess credits to offset future generation, but the NEM 2.0 customer has $0.50 of NBCs accumulated that can't be offset by any future production

Over the course of a year a household can accrue substantial NBCs.

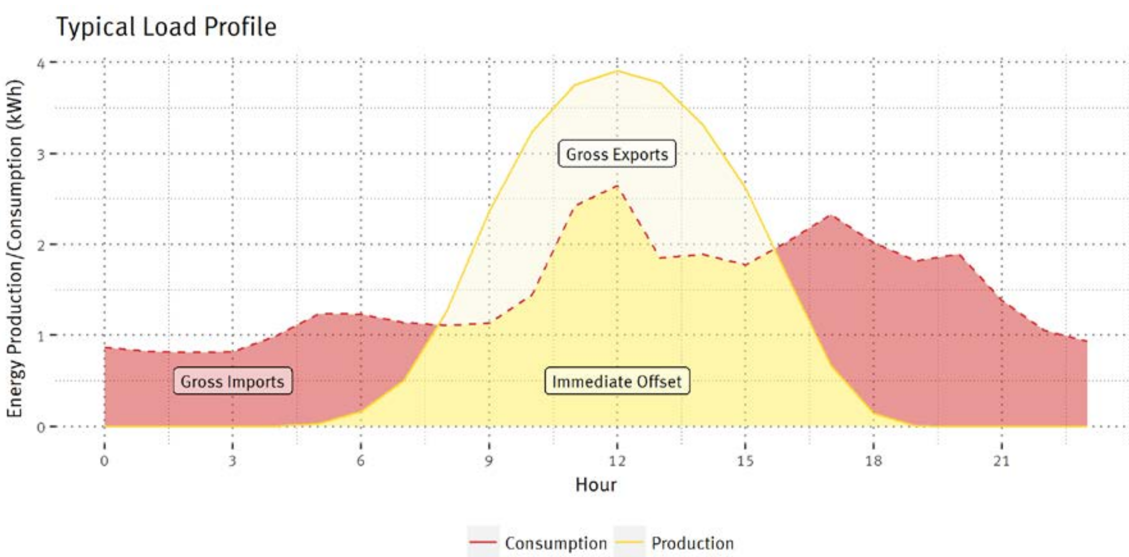


Figure 1: Consumption and production profiles for a case study house

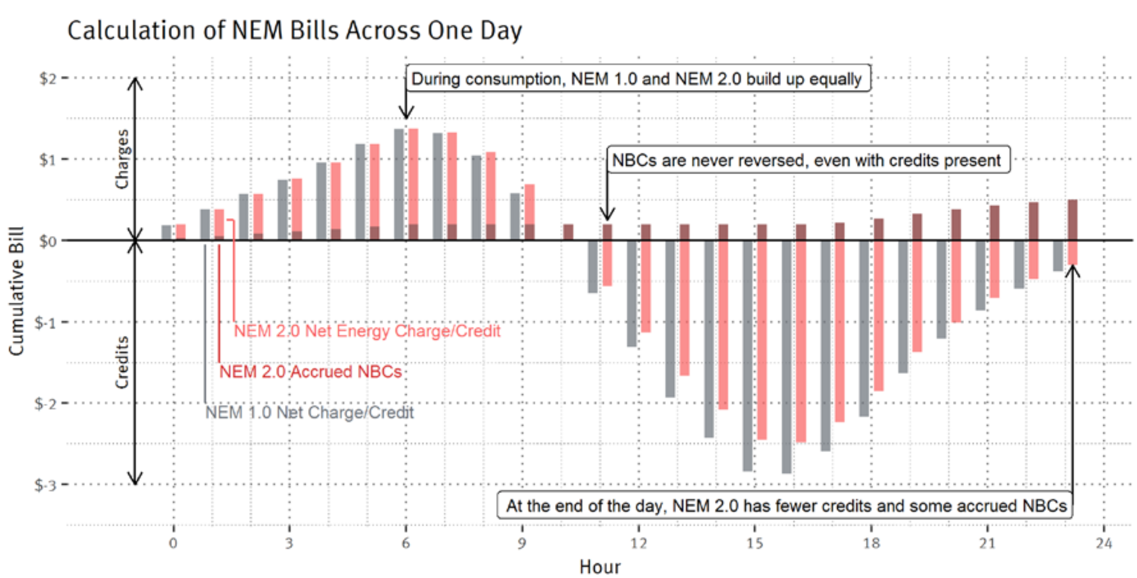


Figure 2: Comparison of NEM 1.0 and NEM 2.0 bill changes

Part 1: Case Study

Introduction

In order to examine how the change from NEM 1.0 to NEM 2.0 would affect the financial outcomes of real proposed residential PV projects, we evaluated 630 residential PV projects in Aurora's database. While existing projects that use the NEM 1.0 schedules are grandfathered in for 20 years, the findings of this study indicates a general trend for how NEM 2.0 changes the financial outcome of new solar projects. We selected the 630 projects because they had the following characteristics:

1. The residences were all in California and were currently on a NEM 1.0 billing regime. This was important for us to evaluate the difference in the financial returns to the project under NEM 2.0 vs NEM 1.0
2. The residences all had interval (Green Button) data[3]. Green Button data allowed us to see how much energy each household was consuming on a 15 minute interval. This was critical for calculating the effects of a switch to TOU rates.
3. The residences had real proposals, designed by solar professionals who were aiming to win the homeowner's business by maximizing their savings

The combination of these characteristics allowed us to analyze a rich corpus of actual proposed solar installations, as opposed to simulated projects. To calculate the financial returns of each installation, we focused on the net present value and payback period metrics. We used the homeowner's actual pre-solar utility bill, which we calculated from the Green Button data that the installer uploaded into Aurora, and the pre-solar utility rate that she selected. Our assumptions are listed below:

Utility Bill:

- The post-solar utility rate was selected as either a residential tiered rate or a residential TOU rate, depending on which provided a lower utility bill
- The net surplus compensation rate was set to $0.03/kWh, approximately the average for California in 2016
- The monthly minimum charge was set to $10.00, the approximate value for all of California's major IOUs
- The NBC portion of the utility rate was set to $0.025/kWh

Net Present Value:

- A system cost of $3.00/W was used to determine the cost of the system
- The system was paid for with cash
- The 30% federal ITC was applied and used for deductions in year 1
- The project lifetime N is 25 years
- Systems have a 0.5% annual age loss, linearly compounded
- Utility escalation was 2.0%, geometrically compounded annually
- The homeowner discount rate d was 3.0%

The equation for NPV is:

$$NPV = \sum_{i=0}^{N} \frac{Cash\ Flow_i}{(1+d)^i}$$

Where Cash Flow is the system cost in year 0 and the difference in pre-solar and post-solar bills for years i = 1 through 25. The ITC is a positive cash flow included in year 1.

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[3] http://blog.aurorasolar.com/the-value-of-green-button-data-for-solar-customers/

Project Filtering:

- Projects that had a negative NPV under these parameters were removed from the study
- Some projects contained negative values in the uploaded Green Button Data consumption profiles. This indicates existing generation sources, so these projects were not analyzed further
- Projects with less than 40% and greater than 120% annual offset were removed from the set since these are not typical designs

Summary of Systems

Table 1: Summary of Case Study Designs

	Min	1Q	Median	Mean	3Q	Max
System Size (W)	1,860	5,105	6,715	7,357	8,827	23,940
Energy Offset %	40.1%	88.5%	98.9%	93.4%	101.6	119.9%

The systems analyzed range from 1.8 kW all the way up to 24 kW, and have a wide range of energy offset targets. About half of the systems aim to completely offset the energy usage in the household. Most of the systems designed in Aurora aim to offset over 90% of household energy production, and 50% of systems offset greater than 99% of household energy usage. To look into the financial returns for the systems designed above, we compared the energy reduction against the utility bill reduction. Figure 3 shows the range of energy offset % and utility bill savings under NEM 1.0.

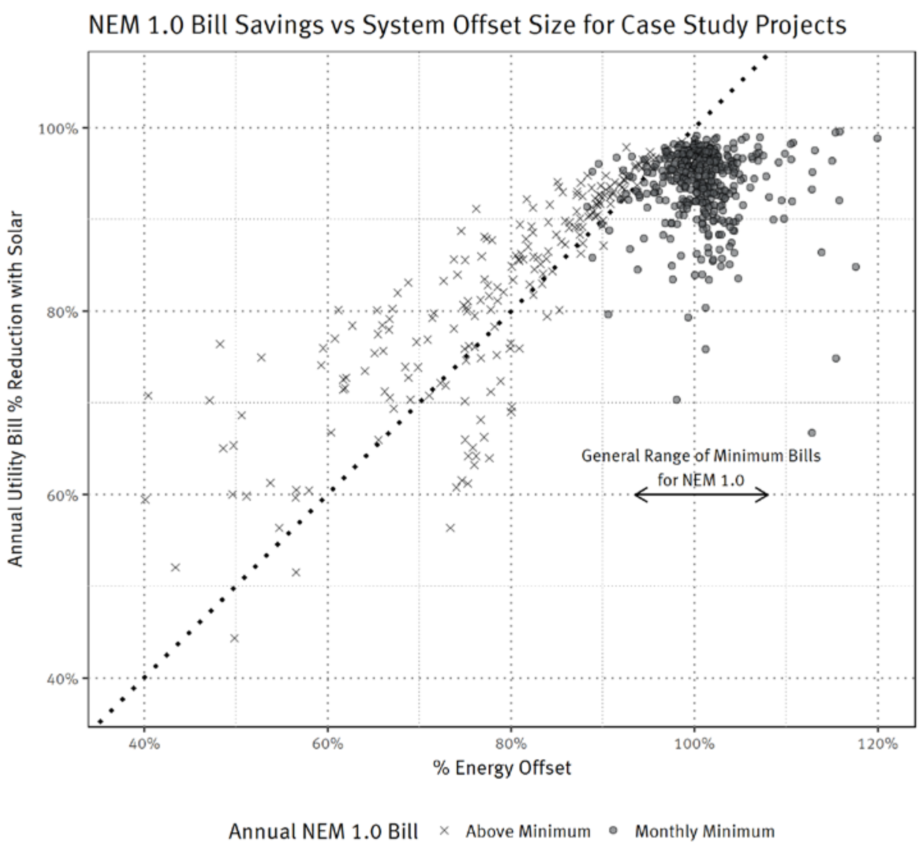

Figure 3: Comparison of NEM 1.0 Bill Savings % vs Annual Energy Offset %

It is important to note that each kWh imported or exported from a building is not valued equally – in a tiered rate structure, NEM customers offset their most expensive tiers first, and in a TOU structure energy imported or exported during peak hours at a higher rate. As a result, many households have a higher percentage reduction on their utility bill compared with the percentage offset of their energy usage. Stated differently, small capacity designs that offset more expensive electricity result in a higher return on investment than larger designs). The black dotted line shows the 1:1 line of energy offset to bill savings; systems above this line offset a higher percentage of their total bill than their energy offset percentage.

At higher ranges of annual energy offset, some systems begin to reach minimum year 1 bills at as low as 87% energy offset, although it usually takes close to 95% offset to achieve the minimum bill. Above this point the systems see diminished returns for increases in system size because the excess energy is converted into wholesale credits, valued at only $0.02 – $0.05 per kWh, rather than at market rates. Achieving the minimum bill is also the target for maximum net present value of the system, since this offsets as much of the costly electricity charges as possible without oversizing the system for minimal returns.

Financial Impact of NEM 2.0

Table 2 summarizes the bill savings in both NEM 1.0 and NEM 2.0 scenarios for the Case Study homes, as well as the accrued NBCs. Financially, under NEM 1.0 these systems save a mean of 89.5% of the utility bill, which is a bit less than the offset percentage size due to minimum charges. Under NEM 2.0, these systems see a mean savings of 86%. Stated differently, for the exact same system, switching from NEM 1.0 to NEM 2.0 reduced the mean savings on a utility bill by about 3.5 percentage points.

The accrued NBCs are substantial and in some cases double or quadruple the annual bill from NEM 1.0 to NEM 2.0, but it's important to keep track of the bill savings rather than the bill changes. In addition, the actual difference in NEM 2.0 and NEM 1.0 bills is smaller than the accrued NBCs, with a mean of $121 and a median of $100 increase rather than the $175 accrued NBCs. The cause is that the energy charge component of most projects drops, and that some of the bill for many NEM 1.0 designs consists of monthly minimum charges, which means the full bill increase will be less than the value of the NBCs. The average decrease in net present value of the projects is about -$2550 over the lifetime of the system, or about $100 per year. The payback period is on average 4 months longer.

Table 2: Summary of Financial Savings and Accrued NBCs for Case Study Houses

	Min	1Q	Median	Mean	3Q	Max
Bill Savings % Under NEM 1.0	44.4%	86.9%	92.6%	89.5%	95.6%	99.6%
Bill Savings % Under NEM 2.0	40.78%	83.0%	89.2%	86.0%	92.3%	97.8%
Accrued NBCs	$37.72	$117.00	$155.90	$173.80	$208.60	$628.40
Bill Increase from NEM 1.0 to NEM 2.0	$0.00	$47.34	$100.00	$120.80	$161.50	$564.20

Table 3: Changes in financial metrics from NEM 1.0 to NEM 2.0

	NEM 1.0	NEM 2.0	Change	S.E.
% Annual Bill Savings	89.5%	86.0%	-3.5%	2.3%
NPV	$38320	$35770	-$2548	$1604
Payback Period	6.4 yrs	6.8 yrs	+0.37 yrs	0.52 yrs

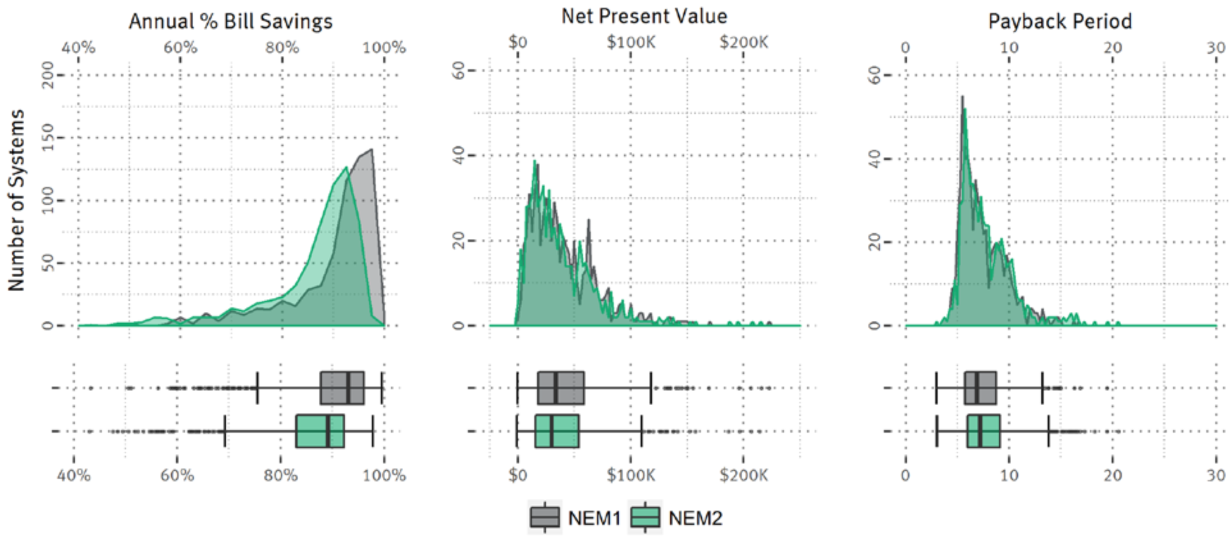

Figure 4: Distribution of Financial Changes from NEM 1.0 to NEM 2.0

Differences in Impact Between Tiered and TOU Rates

One of the changes in NEM 2.0 is that it is now mandatory to enroll in a TOU rate schedule, whereas in NEM 1.0 the customer could elect to stay on their existing tiered rate. An NREL study from 2012 noted that in about 20% of cases, TOU rates were unfavorable for solar customers [9]. Within the 630 projects we analyzed, we found that 276 (44%) of the load profiles and production profiles favored keeping a tiered rate under NEM 1.0, likely due to differences in California TOU rates compared with the rest of the country. A study by Greentech Media [10] found that households with an average amount of electrical consumption may do best under TOU rates while high-energy usage home would benefit the most with tiered rates and solar, but in our case with only an afternoon-peak TOU rate or a 3-tiered rate available there was no significant difference in annual consumption between projects benefiting from TOU or tiered.

Consumption profiles that either have a large portion of energy usage at night – such as households with nighttime electric vehicle charging, or with PV production in the afternoon will typically see better electricity savings under a TOU rate plan. Systems that have high consumption during peak hours or solar panels oriented further east will do better with a tiered plan. Customers with high off-peak consumption, including EV users, benefit the most from switching to a TOU rate for solar.

In the following sections, we will analyze the financial changes for NEM 2.0 for the two types of load profiles separately. Among projects that benefit from switching to a TOU rate when going solar, the increases in utility bill are straightforward to calculate. However, for the homes that do better on a tiered rate, the impact of NEM 2.0 is greater and depends heavily on the load profile.

Financial Impact for TOU-type Load Profiles

To make sense of the financial outcomes for TOU-favored projects, we classified the differences in NEM 1.0 and NEM 2.0 bills into four distinct cases. Each of the four cases has a separate equation to model the cost increase from NEM 1.0 to NEM 2.0.

The cases are:

Case 1: No difference in NEM 1.0 and NEM 2.0 Utility Bill
Case 2: Cost increases from NEM 1.0 to NEM 2.0 driven by NBCs
Case 3: Cost increases from NEM 1.0 to NEM 2.0 driven by Energy Usage
Case 4: Cost increases from NEM 1.0 to NEM 2.0 for systems that don't fully offset energy bills

Cases 1, 2, and 3 all describe projects that offset enough energy charges to the point that the NEM customer is only paying monthly minimum charges. Case 4 is for all projects that still have energy charges greater than the monthly minimums under NEM 1.0.

Figure 5 below compares the non-bypassable charge component the NEM 2.0 annual bill against the increase in the annual utility bill. Among the first 3 cases, some of them have no energy charge. In the 4th case, the energy charges under NEM 1.0 are greater than the minimum bill, and with the inclusion NEM 2.0 some NBCs are added in on top of that. The energy charge under NEM 2.0 may go up or down depending on the household's net consumption on the year.

Nearly all projects have a smaller bill increase than just the NBC assessed – we're not seeing bills fly up by the $170 mean NBC charge, but increases closer to $120. Next we will look more in depth into the four different characteristics.

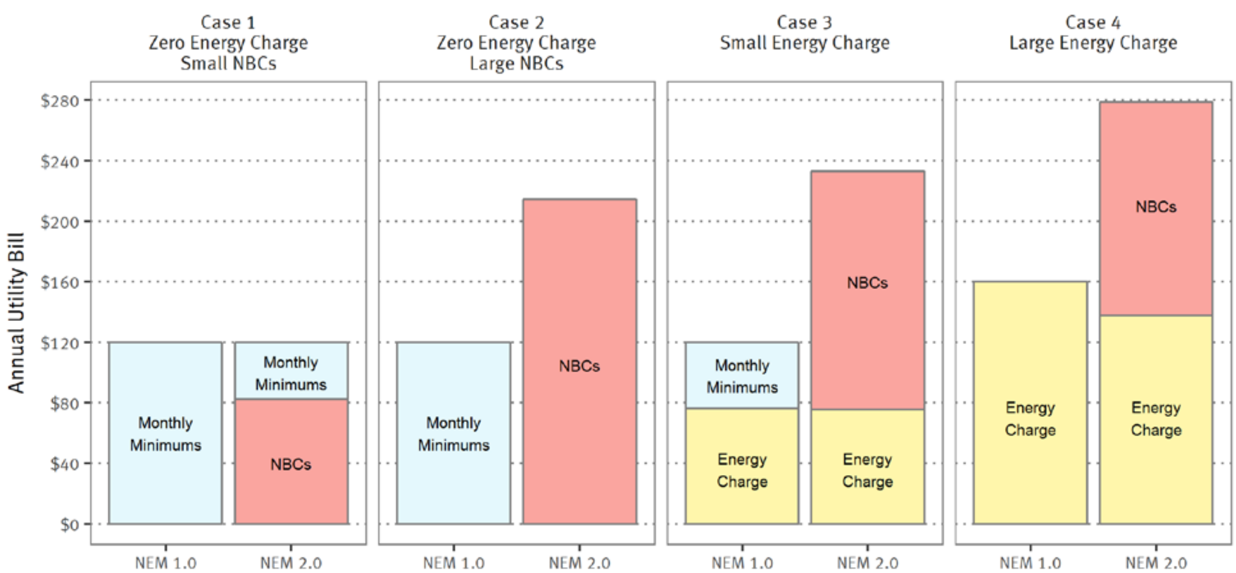

Figure 5: Four Classes of Bill Differences Between NEM 1.0 and NEM 2.0

Calculating the Cost Changes

The flowchart in Figure 6 shows how to sort systems into the 4 categories. To organize, the energy charges under NEM 1.0 and the system size need to be known. For example, a system that has $70 of energy charges in NEM 1.0 would fall into case 3.

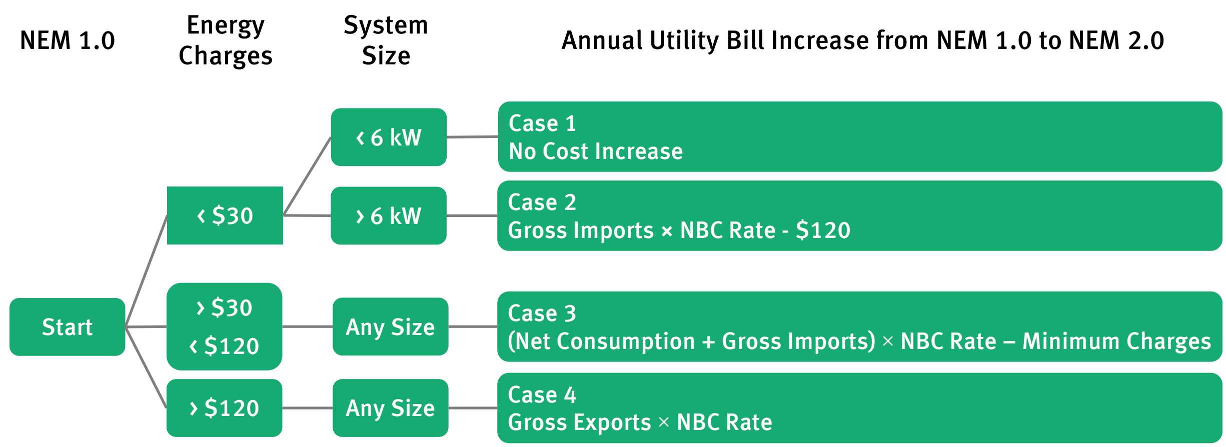

Figure 6: Flowchart to Classify Case Study Projects

Case 1: Small systems with high percentage offsets

Systems that fit into case 1 require systems under 6 kW to reduce energy charges to $30 or less for a whole year. These are often oversized for year-1 production with the intention of keeping the homeowner's bill at the minimum rate for as long as possible. In NEM 2.0, the NBCs accrued are still less than $120 so they still pay the minimum bill on the year.

$$Cost\ Increase = \$0$$

Case 2: Larger systems with high percentage offsets

Some system designs go larger than 6 kW with the same goal as case 1 – keep the customer's bill at the minimum threshold as long as possible. However, these homeowners pull enough electricity from the grid throughout the year to drive their accrued NBCs above the $120 minimum bill threshold. As a result, they pay a little bit more than the minimum bill.

$$Cost\ Increase = Gross\ Imports \times NBC_{rate} - \$120$$

Case 3: Systems optimized for only year 1

The third case of systems also have minimum bills in year 1, but aren't designed to keep the customer's bill at a minimum level in future years after panel degradation. The energy portion of the bill is somewhere above $30 in the NEM 1.0 scenario. Under NEM 2.0, systems with these sorts of designs have a large enough increase in NBCs to drive them above the minimum charge. An approximation of the difference in cost between NEM 1.0 and NEM 2.0 for these systems is as follows:

$$Cost\ Increase = Net\ Consumption \times NBC_{rate} + \ Gross\ Imports \times NBC_{rate} - Min.Charges_{NEM1}$$

Case 4: Systems that pay above monthly minimums in year 1

The last group of systems have energy charges greater than the minimum delivery charges under NEM 1.0. The energy charge component of the bill tends to shrink somewhat under NEM 2.0. The cost increase from NEM 1.0 to NEM 2.0 is somewhat counterintuitively the amount of electricity *exported* to the grid. This arises from the fact that NEM 2.0 customers don't receive the NBC portion of the rate on net exports.

$$Cost\ Increase = Gross\ Exports \times NBC_{rate}$$

Across the board, the financial impact of NEM 2.0 policies can be minimized by aligning production and consumption to avoid building up NBCs. We will look in depth at the most-impacted projects in case 4 next.

Changes for Case 4: Consumption Offset Metric

Non-bypassable charges are based on energy purchased from the grid, so managing the design of a PV array to offset as much energy as possible rather than exporting most to the grid and buying it back later will help to reduce the accrual of NBCs. We introduce a new metric, called the Consumption Offset Metric (COM). The metric shows how much of available energy produced is used to immediately offset consumption.

$$COM = \frac{Immediate\ Offset}{\min(Total\ Consumption, Total\ Production)}$$

COM ranges from 0 to 1, with higher numbers indicating that more of electricity is immediately used. A system that immediately uses all production from the PV system will have a COM of 1. Seen in Figure 7, lower COMs might be indicative of oversized systems or late night power usage, such as that from an electric vehicle. Mid-ranked COMs might have higher energy usage outside of the peak production, or an oversized system. Higher values of COM indicate undersized systems or high mid-day usage.

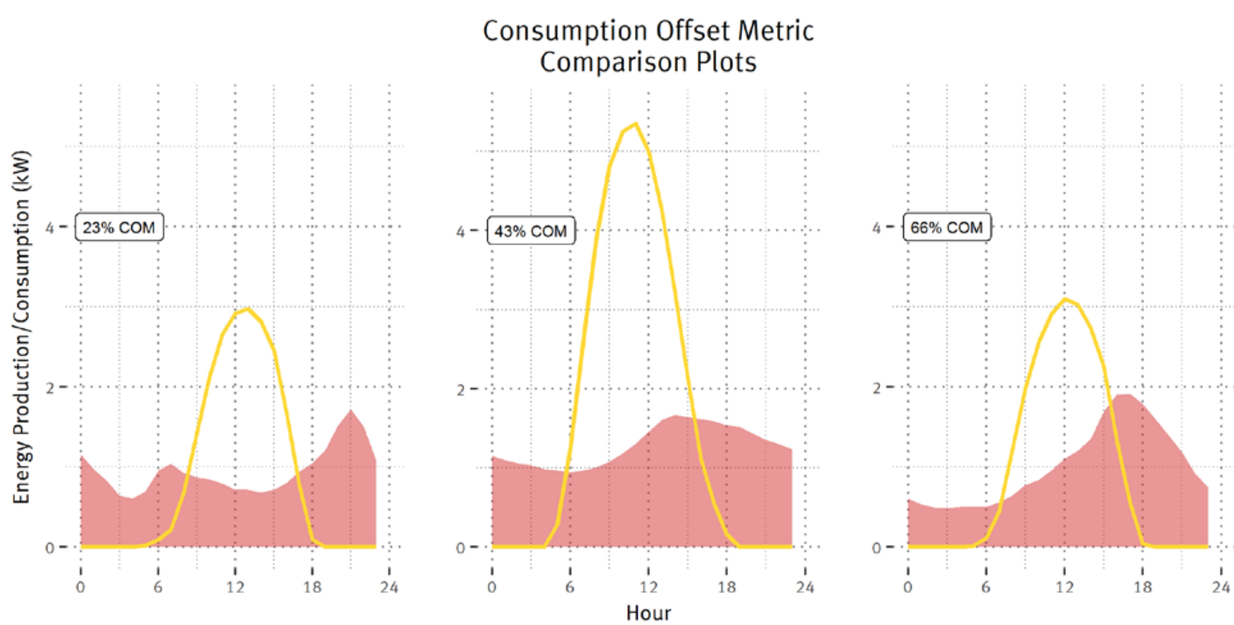

Figure 7: Consumption Offset Metric

Among projects in case 4, the largest impacts are well correlated with moderate values of COM. Sites that have a poor COM – where production and consumption are misaligned – see bill savings losses around 2 percentage points since these are fairly close the minimum bill and retain a high savings percentage. At 35-55% COM, savings losses are closer to 3.6 percentage points. Sites which higher COM values exhibit less of a bill savings reduction since fewer NBCs are accrued, seeing around 2.5 percentage points losses. Figure 8 shows that the sites with the lowest COM fare worse under NEM 2.0.

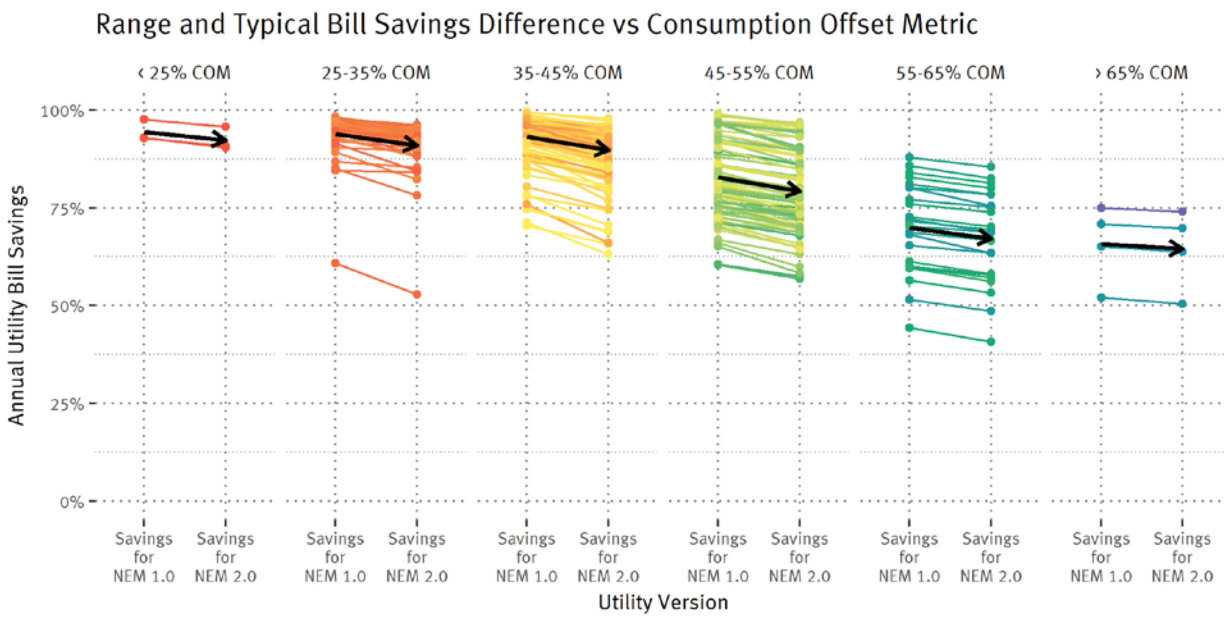

Figure 8: Drop in utility bill savings as a function of COM
Each pair of points is an individual case study house, and the decline shows the percentage of bill savings lost between NEM 1.0 and NEM 2.0. Black arrows show the average change in bill savings for each category

Financial Impact for Tiered Projects

For households that have a lower post-solar bill with a tiered rate, the introduction of NEM 2.0 policies presents two significant changes – both the inclusion of NBCs and the mandatory enrollment in a TOU rate. Figure 9 indicates the relative impact of each change. Most points lie above the 45 degree line, indicating that NBC policy actually increases bills more than the mandatory TOU rate. The left side of the figure is the same style as the COM plot in Figure 8, with each project represented as a line and the annual bill savings percentage for those projects indicated with dots at the 3 billing versions. The relative slopes also indicate that the addition of NBCs reduces savings by more percentage points than the switch from a tiered to a TOU rate.

	Min	1Q	Median	Mean	3Q	Max
Difference between Tiered and TOU Rate	$0.06	$4.40	$11.92	$34.37	$42.24	$221.20
TOU NEM 1.0 to TOU NEM 2.0	$0.00	$64.16	$116.70	$126.50	$177.00	$436.70

After accounting for the changes from Tiered to TOU rates, the increase in annual bill calculations follow the same steps as TOU projects. Overall, designs that perform better in a tiered rate structure do worse in the switch to the NEM 2.0 policy, but the effect is smaller relative to the increases in NBCs.

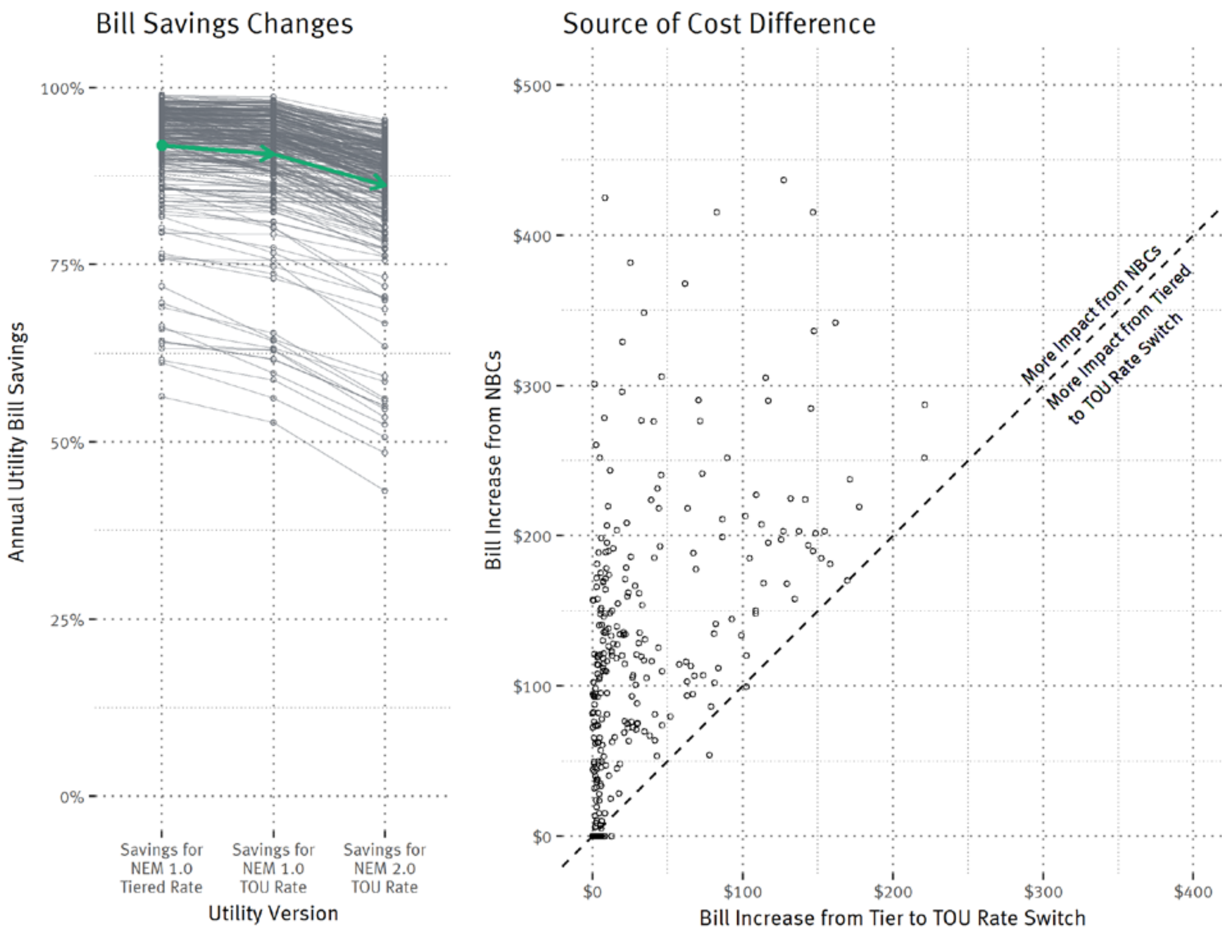

Figure 9: Comparison of cost change sources from NEM 1.0 + Tiered to NEM 2.0 + TOU
Left: Annual % bill savings for projects across 3 billing versions. Right: scatterplot attributing cost increases to either the Tiered to TOU rate switch or the NBCs in NEM 2.0 billing. Most projects have a greater impact from the NEM 2.0 rules compared with the switch from Tiered to TOU

Revisiting Bill Savings under NEM 2.0

Looking again at the plot of annual bill reduction percentage vs energy offset percentage, we see that the rate of return tapers off around 85% instead of at 95% due to the inclusion of NBCs. However, this doesn't indicate what an optimal system size is under NEM 2.0, since the homeowner's discount rate might keep those returns attractive despite the inclusion of NBCs. In addition, higher energy offset values are required to meet the minimum bill target to maximize net present value, which indicates that larger systems may now be optimal.

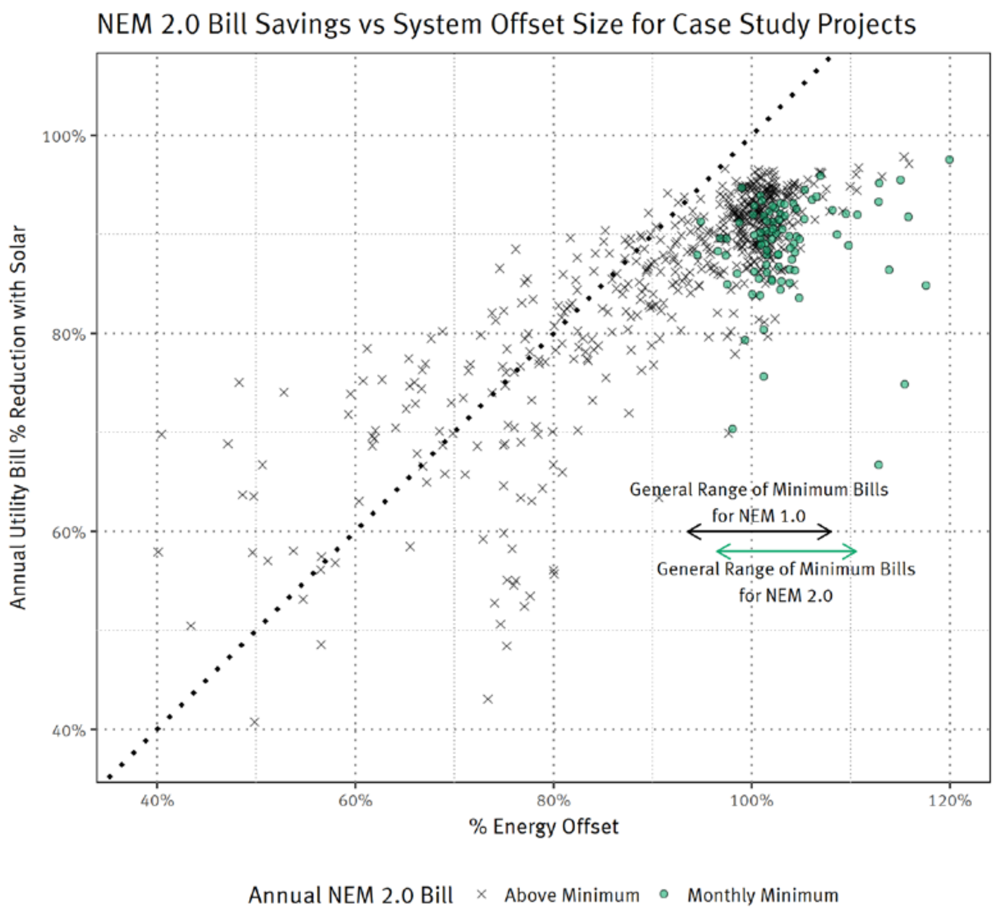

Figure 10: NEM 2.0 Bill Savings vs System Offset

In conclusion, from the analysis of over 600 projects designed in Aurora, we found the following financial impacts:

- The median difference in NEM 1.0 and NEM 2.0 utility bills is about $100/year
- The average payback period is about 4 months longer
- This represents a 3-4% decrease in the value of PV systems for homeowners
- On the consumer end, the impact of NEM 2.0 is highest households that aren't offsetting their entire electricity load and is also worsened with poor alignment between production and consumption profiles

In part 2 of this study, we investigate how installers can optimize system design under NEM 2.0.

Part 2: Parametric Study

When looking at NEM 1.0 and maximizing the returns on solar, the peak TOU period and the total energy production are the two primary concerns for optimizing system design. With NEM 2.0 in place, the alignment of production with consumption profiles to minimize NBC accrual becomes a third factor that influences the optimal design. Conceptually, it would make sense for a customer who has low mid-day consumption but high late-afternoon peak in consumption to push their solar production later in the day, but this behavior may already be incentivized by late TOU periods. To answer this question, we used Aurora to ran a parametric model on 50 sample sites to determine how optimal orientations and financial metrics change from NEM 1.0 to NEM 2.0.

Production profile shifting

In part 1 of the study, we kept the design of the PV arrays fixed while inspecting the impact of changing from NEM 1.0 to NEM 2.0. This section of the study looks at another variable — the system orientation — and looks to see if any rules of thumb about the design of the PV array should be changed to account for NEM 2.0. If the production can be lined up with consumption, thereby improving the COM, or if more production occurs during on-peak hours, increasing the dollar value of exported electricity, it might be possible to obtain more favorable financial outcomes for solar customers.

How much can production be shifted?

The direction that an array faces effects when it produces the most power. An array facing east generates more energy in the morning; one facing south towards the equator maximizes production at noon, and west later in the day. Barring factors such as shading or extreme amounts of morning fog, the equator facing-array will out-produce a system facing to the east or west. Figure 11 below shows the daily average output of three hypothetical arrays in Los Angeles, CA, with a tilt of 30 degrees and facing south, southwest, and due west. The peak production for this south-facing array occurs at 11:50 am; moving 45 degrees west to 225 degrees azimuth moves the peak production time 70 minutes further, and going all the way to the west nets another 30 minutes. Since the energy output of the 270 degree azimuth array is substantially lower, it increased production during high-valued peak TOU may not be enough to offset the loss in overall production.

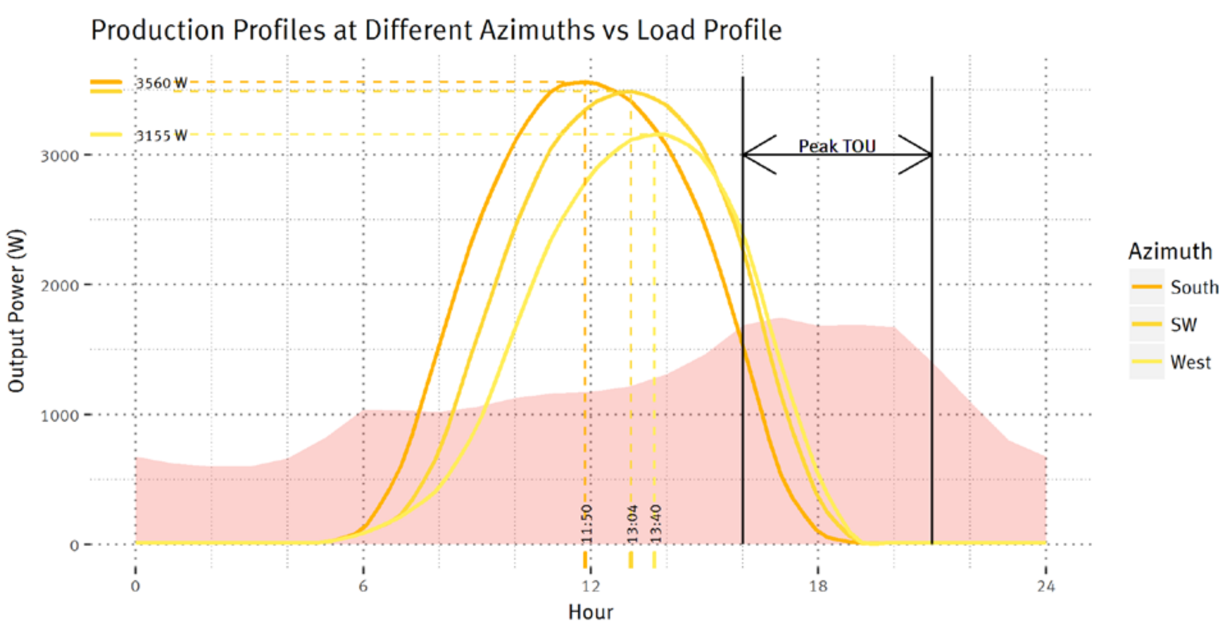

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Figure 11: Production profiles for three different designs in Los Angeles, CA

Table 4: Comparison of production profiles

TOU Peak Hours	Azimuth	180 S	210 SSW	225 SW	240 WSW	270 W
	% production loss	-	-0.8%	-2.9%	-6.1%	-14.9%
Peak 3pm-8pm	% production during peak	12.4%	17.9%	20.3%	22.5%	25.5%
	% peak production above south-facing	-	42.5%	58.6%	69.5%	74.8%
Peak 4pm-9pm	% production during peak	5.0%	8.4%	10.0%	11.4%	13.6%
	% peak production above south-facing	-	66.6%	94.4%	115.1%	132.0%
	Consumption Offset Metric	45.2%	46.7%	47.7%	48.8%	52.6%

Table 4 summarizes the reduction in total energy production compared to a south-facing array, the percent of production during peak TOU hours, and the percent of additional production during peak TOU hours compared to the south-facing array. Arrays pointing further to the west have greater production during peak hours, but have drastic losses in total production. The west-most array produces 8.8% less than the WSW array, but still has a greater amount of on-peak energy generation, which could still help boost the returns.

For southern sites such as Los Angeles, the window of production peaks spans from 10:40 am at 90 degrees azimuth to 1:40 pm at 270 degrees azimuth. Sites further from the equator have a slightly wider window of peak production times but only by about 5 minutes on each side. Another important factor is morning weather, as sites further inland and away from the ocean have a larger morning window. The overall room for manipulating peak production is about 3 hours for most cases, but can still drastically increase on-peak production.

The Consumption Offset Metric that we found to be important for determining the difference between NEM 1.0 and NEM 2.0 bills also increases for systems pointed further west since this consumption profile has higher consumption during on-peak hours, however the increase in the metric is small in comparison to the growth of on-peak production.

To look further into whether shifting the array west is a viable solution, we ran a parametric analysis across the template sites, along with several typical load profiles, with the goal of determining if the rules of thumb for optimal system design will change under NEM 2.0.

Parametric Study Setup

For this parametric study, we selected 50 cities in California with TMY3 weather stations, representing the large population centers and all 16 climate zones defined by the California Energy Commission. The locations are shown in the Figure 12 map. Simple PV arrays consisting of 2600 W modules were simulated with combinations of azimuths between due east and due west and tilts ranging from horizontal to 45 degrees. The production from these prototypical arrays was then scaled to represent systems ranging from 2000 W to 5500 W DC power rating.

We then ran the set of scaled production profiles for all 50 locations in combination with a set of typical load profiles through our financial model for NEM 1.0 billing and NEM 2.0 billing with NBCs, using the same financial parameters as in part 1 of this study. For NEM 1.0, we selected the local tiered rate, and for NEM 2.0 we used the local TOU rate – either PG&E ETOU-A, SCE TOU-D-A, or SDG&E TOU-DR.

Figure 12: Map of the 50 parametric sites analyzed
Each of California's 16 climate zones is represented by a different colored block. Map: Google Map Engine. Climate Zone data: CEC

The combination of 50 locations, 130 orientations, 8 system sizes, and 8 load profiles gives 416,000 combinations, which are each run under both NEM 1.0 and NEM 2.0 for a total of 932,000 financial calculations.

Clustered load profiles

For the typical load profiles used in this study, we took all of the California-based interval data and used k-means clustering to produce 8 "typical" load profiles to represent the houses. These load profiles are scaled to 7000 kWh annual consumption, which represents a typical Californian home [11].

These load profiles represent a variety of home usage types to see if any particular profiles are more heavily impacted under NEM 2.0 than others.

A. Evening/night usage – "EV User"
B. Morning and evening usage – "Early Riser"
C. Evening usage – "The 9 to 5 worker"
D. Mid-day usage – "Work from Home"
E. Light morning and heavy evening – "Family with kids"
F. No night and peak TOU – "AC hog"
G. Higher baseline, early afternoon peak – "Flat AC"
H. Heavy late-night usage – "Super Chef"

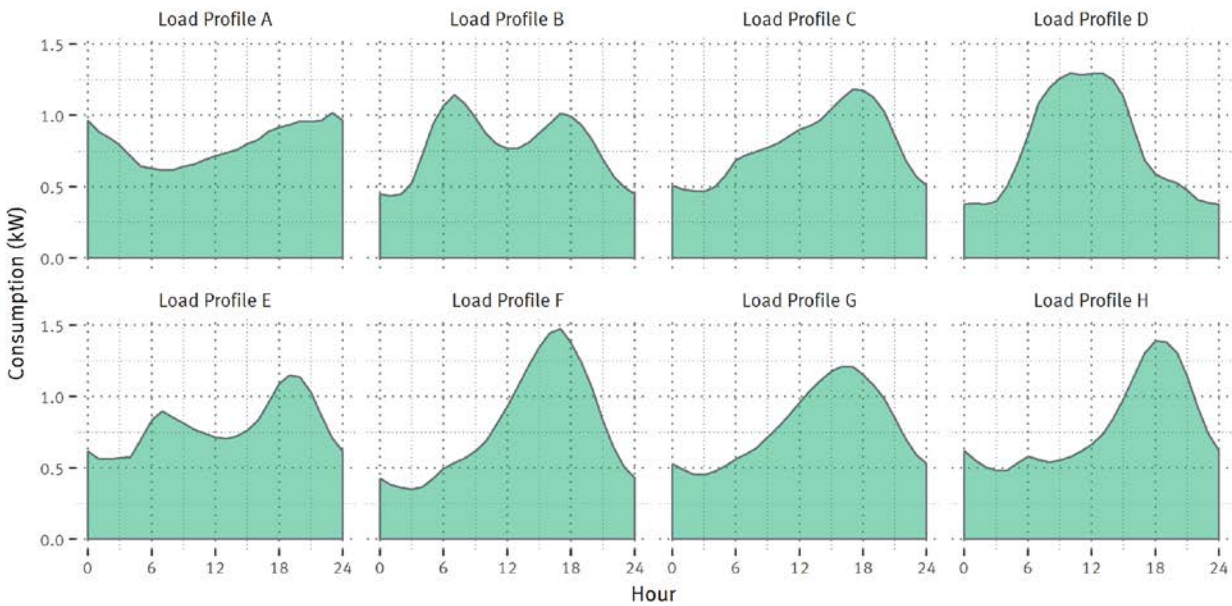

Figure 13: The 8 clustered load profiles used for this parametric study

Analysis

For each combination of site, load profile, and system size, we determined the annual utility bill under NEM 1.0 on a tiered rate and NEM 2.0 on a TOU rate across all combinations of tilt and azimuth, and then determined which orientations resulted in minimized bills for those profiles designs.

Example diagnostic combination plot

Diagnostic matrix plots for each city were created during the study. Figure 14 below shows the results for San Francisco as an example. The combination of 8 load profiles and 8 system sizes produce 64 squares. Each square has the range of azimuths on the x-axis and the range of tilts on the y-axis. Open dots indicate the optimal tilt and orientation combinations under NEM 1.0 – multiple dots may be present if multiple orientations resulted in the same bill. Red dots indicate the same for NEM 2.0. Dots in different locations would indicate shifting optimal orientations; as seen below for the plot in San Francisco. In many cases there was little change between the two scenarios.

The background color indicates the system offset. Systems just below 100% offset tend to have a wide range of ideal orientations because they offset their bill down to just the minimum charges in a large combination of tilt and azimuth, but do not receive any net surplus compensation without excess kWh production. Projects that exceed 100% energy offset are nearly always earning net surplus compensation, which means that the optimal system design is the one that produces the most energy in both NEM 1.0 and NEM 2.0.

In the case of San Francisco, we can see that the red dots are typically slightly to the west of the grey circles, indicating that under NEM 2.0, systems should be designed slightly further to the west from NEM 1.0. We used these plots and the underlying numbers to look at differences in the best orientation between NEM 1.0 and NEM 2.0, and the financial impact from the new policy.

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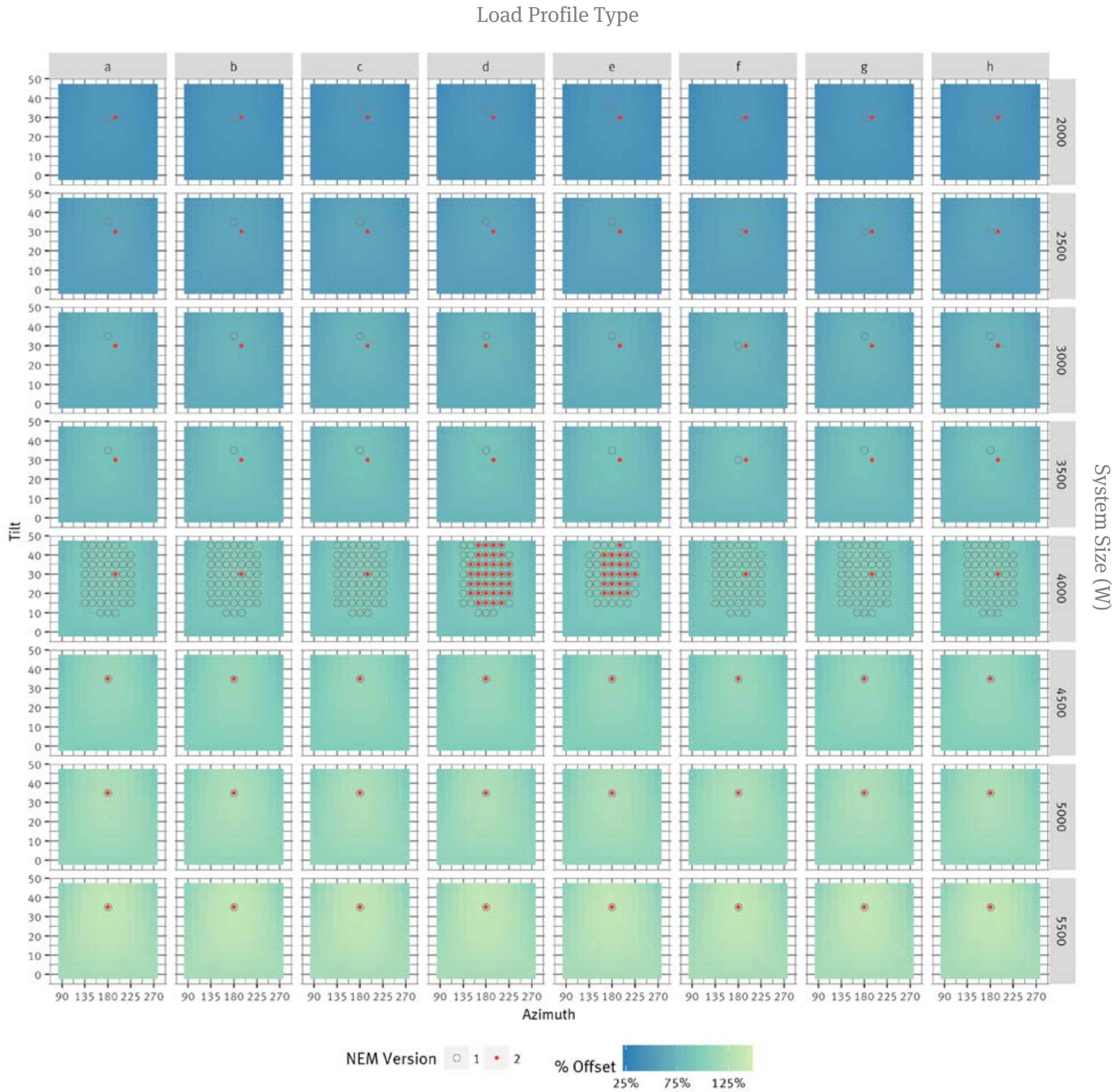

Figure 14: Combination plot for San Francisco
Each square contains the results for a pair of load profiles and system sizes. Grey circles indicate the NEM 1.0 designs with the lowest annual bill for that square; red dots indicate the same for NEM 2.0. Differences in dot placement mean that the optimal design is different between NEM 1.0 and NEM 2.0

Summary of Best Practices for NEM 1.0 and NEM 2.0

Optimal azimuth:

Under a tiered utility rate in NEM 1.0, the mean azimuth across all sites that minimizes the annual utility bill is 184 degrees and the median is 180 degrees. This is anticipated, since a tiered rate structure simply favors producing as much power as possible. Switching to a TOU utility rate with NEM 2.0 policies, the mean optimal azimuth shifts to 194 degrees with a median of 195 degrees, further to the south compared to the optimal designs under NEM 1.0.

There is little variation in the optimal azimuth between the 8 typical load profiles, indicating that the TOU rate structures with afternoon peak consumption hours are the driving force to point systems further west. To double-check this conclusion, we also ran the parametric study numbers using NEM 1.0 with TOU rates to find the optimal azimuth for each location-profile combination, and found that there was no change in the optimal azimuth from NEM 1.0 to NEM 2.0. NBCs are not a major driving force in system orientation.

Optimal tilt:

Among the analyzed projects, the optimal tilt was not correlated with the latitude of the site. Each dot represents the mean best tilt for a site, load profile, and system size combination. Projects in NEM 2.0 tend to be slightly biased towards higher tilts, which improve production in the winter at a detriment in the summer. By increasing the winter production, less gross consumption occurs in the seasons where production is at its lowest, resulting in reduced NBCs.

Optimal system size:

In addition to favoring west-facing systems, systems optimally designed under NEM 2.0 have a surprising characteristic: larger systems will result in a better net present value. Figure 15 shows curves for the year 1 annual bill and the net present value of a project in San Francisco for both NEM 1.0 – TOU and NEM 2.0 – TOU. The results for NEM 1.0 – tiered are similar. The NEM 1.0 bill curve flattens out around 90% energy offset, while it takes a full 96% offset under NEM 2.0 to reach that minimum bill. The maximized NPV for NEM 1.0 is at 95%, and for NEM 2.0 NPV is maximized at 105%. At higher offset percentages, the NPV falls because the additional system cost outweighs the net surplus compensation for that excess production.

It's important to note that for these systems, the NPV for the NEM 2.0 design is worse than the NPV of the NEM 1.0 design, even when comparing the systems optimized around their respective rate schedules. At every large system offset sizes, the results are identical because they are driven by net surplus compensation.

If system degradation, and utility rate escalation are not considered in NPV calculations, the system size at which the annual utility bill is first minimized is also the optimal sizing for maximizing NPV. Degradation and rate escalation mean that in future years, the system that just hit the minimum bill target in year 1 will have a bill greater than that at a future year, so there is still room to increase the system size to maximize financial returns.

The reason that the NEM 2.0 NPV is maximized at a higher energy offset percentage than in NEM 1.0 has to do with the components that go into the minimum bill. In NEM 1.0 the minimum bill is achieved as soon as the energy charge falls below $120. In NEM 2.0, it's when both the accrued NBCs and energy charge are less than $120, or when the energy charge is $0 if the NBCs are greater than $120. This means that there is more room to increase system size before hitting diminishing returns in NEM 2.0.

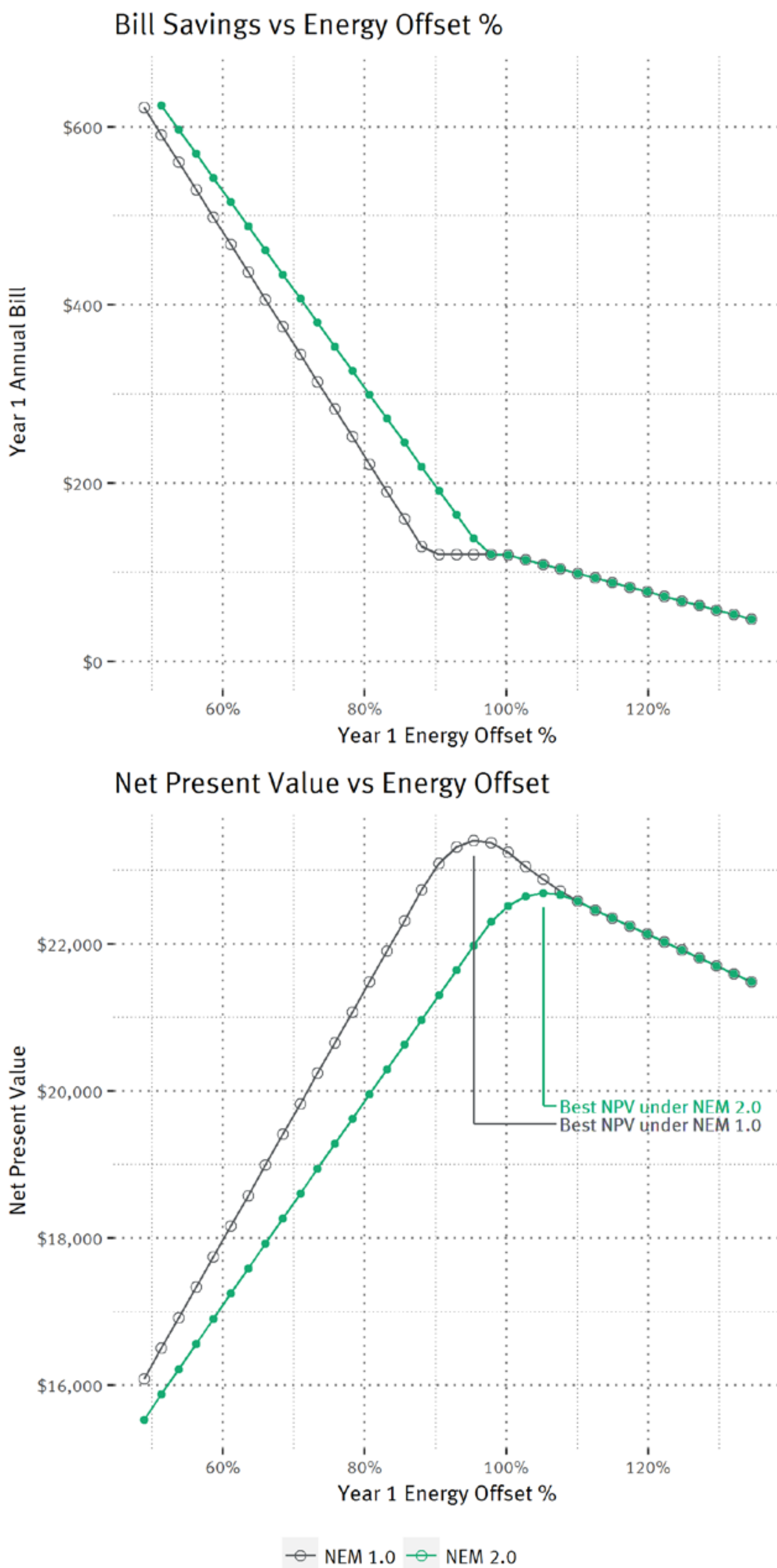

Figure 15: Comparison of year-1 annual bill and NPV for San Francisco

Difference in utility rate schedules

Here at Aurora, we found that over 80% of projects were run with a tiered post-solar rate. So how does the bill savings rate change in the switch from NEM 1.0 to NEM 2.0? We will look just at the projects which have less than 110% offset, as systems with a greater offset tend to exhibit no differences in NEM 1.0 and NEM 2.0 and have a diminished financial return. Figure 16 shows the utility bill savings for a system designed optimally under NEM 1.0 on the x-axis and the savings for the system designed optimally under NEM 2.0 on the y-axis. Points above the 1:1 line indicate a better financial return in NEM 2.0. Each of the three major IOUs is indicated with a specific color.

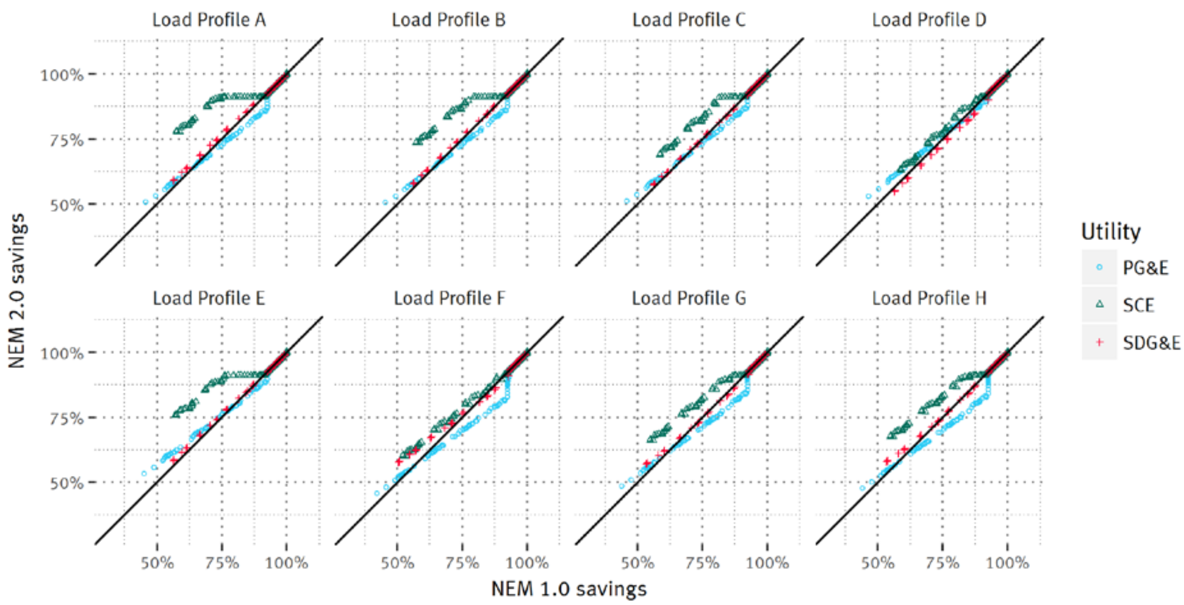

Figure 16: Comparison of savings percentages in NEM 1.0 vs NEM 2.0

For SCE, NEM 2.0 with TOU is almost universally better than NEM 1.0 with a tiered rate. This is a function of the higher rates per kWh in the tiered rate structure and the baseline credit in the TOU rate structure that strongly favor TOU for solar customers. Nearly all SCE customers on any NEM plan will do better with TOU. In PG&E territory, NEM 2.0 TOU is worse than NEM 1.0 tiered in most scenarios. A few load profiles which have avoid on-peak usage do better under TOU than tiered. For SDG&E customers, NEM 2.0 TOU and NEM 1.0 Tiered are about the same: under 80% offset, NEM 2 is better, above 80% NEM 1 is better.

If we do the same analysis comparing a NEM 1.0 TOU project against a NEM 2.0 TOU projects, all points lie slightly below the 1:1 line as expected after the inclusion of NBCs, meaning that all projects fare slightly better in NEM 1.0 than NEM 2.0.

Differences in Design Paradigms

Now that NEM 2.0 is live, what are the differences in best practices for installers? Optimal designs under NEM 1.0 tiered rates simply maximize the electricity output of systems. Systems that are optimally designed under NEM 2.0 tend to point slightly further west, so what's the cost of not changing the design strategy for NEM 2.0 houses?. If the PV system designer does not account for the higher afternoon TOU rates and doesn't increase the system size, customers will end up spending on average an extra $115 per year on their electricity bills.

Conclusion – The New Best Practices

Without changing any system characteristics, Net Energy Metering 2.0 results in a loss of about $100 per year in utility bill costs, but only an average of 3-4% of the savings from solar are affected. Characteristics of a design optimized to maximize NPV in NEM 1.0 include an energy offset of around 95%, which is enough to bring the annual bill down below monthly minimums. An orientation of due south helps maximize production which is ideal for tiered systems.

In NEM 2.0, the ideal system faces slightly west, which capitalizes on the TOU rates. Non-bypassable charges take a small amount of financial returns and penalize homeowners who don't have aligned production and consumption, but these program costs are less influential to system design than the impact from peak TOU rates. Net present value is maximized by systems that are 10% larger than those optimized in NEM 1.0, which is a boon for installers but would drive up install costs.

Glossary of Terms

Annual Consumption – the total amount of energy that a household uses during the year, from all sources. Before a solar PV system is installed, all of this energy would be purchased from the grid.

Annual Production – the total amount of energy that a PV system produces during the year.

Net Consumption – the difference between annual consumption and annual production.

Net Energy Metering – the utility billing process where consumers pay for all energy delivered but are compensated at an equal rate for energy exported.

Total Electric Rate – the market rate for electricity purchased from the grid. This depends on which rate schedule the customer is enrolled in. Some examples include PG&E's E-6 and SCE's TOU-D-A rates. The rate typically ranges from $0.05 – $0.45 per kWh depending on the peak pricing and baseline credits.

Energy Charges – a portion of the total electric rate, which encompasses the generation, transmission, distribution, and a few small charges. These make up the majority of the total electric rate.

Non-Bypassable Charges (NBCs) – the other portion of the total electric rate. Certain programs are financed through revenue that comes out of four specific charges: Nuclear Decommissioning, Public Programs, California Bond Charges and the Competition Transition Charge. NBCs are separated from Energy Charges for accounting and can't be reversed by future production. In addition, NEM 2.0 customers are not compensated for the NBC portion of the rate when they export electricity to the grid.

Gross Exports: the amount of energy exported to the grid over the year. This happens during hours when the PV system produces more energy than is consumed.

True-up Period – the annualized billing cycle for NEM customers in California. NEM customers pay their outstanding electricity balance only at the end of the year

Net Surplus Compensation – a wholesale compensation rate for excess kWh produced over the course of a true-up period

Minimum Delivery Charges – California utilities have a minimum delivery charge, which works out to be about $10 per month. Customers with a Net Metering Schedule will pay these charges each month, and at the end of their true-up period they will either pay the difference between their total energy charges and the $120 already paid, or will receive a small amount of net surplus compensation for excess energy generated.

Gross Imports – the amount of net energy drawn from the grid. This happens during nighttime hours and when the household consumes more energy than the PV system generates.

Immediate Offset – energy produced by the PV system that is immediately consumed by the house.

Consumption Offset Metric – a value from 0 to 1 that indicates what percentage of energy produced by the PV panels is immediately consumed by the house. For systems that produce more than 100% of the energy consumed, COM = *immediate offset / annual consumption*. For projects that consume more than the annual production, COM = *immediate offset / annual production*. The higher the number, the better aligned the production and consumption.

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