UPDATE February 3, 2025: After I posted this reply to McCann, he posted a comment on my associated blog with a link to his reply to my reply. I then posted a reply to his comment. More information on this back and forth at the end of this document.

—---------

Reply to Richard McCann's "How California's Rooftop Solar Customers Benefit Other Ratepayers Financially to the Tune of $1.5 Billion"

By Severin Borenstein, Professor of the Graduate School, Haas School of Business, UC Berkeley and Faculty Director, Energy Institute at Haas

January 27, 2025

In November 2024, Richard McCann posted a webpage and supporting materials[1] asserting that customers of the three large California IOUs who have installed rooftop solar have created an annual benefit to other customers equal to $2.3 billion per year. Sometime in late December 2024 or early January 2025, the assertion and webpage were changed to claim that the benefit is $1.5 billion per year (there is no date on the revised webpage).

In this document, I analyze the claims in McCann's analysis and his conclusion that rooftop solar is actually lowering rates for customers in the IOU territories who do not have rooftop solar.

The McCann analysis is a critique of an August 2024 analysis done by the CPUC Public Advocates Office (Cal Advocates), but McCann claims that the critique also applies to my own work on the subject, which I posted on the Energy Institute at Haas blog on April 22, 2024. In that analysis, I found that residential PV will shift about $4 billion in 2024 onto other ratepayers. I will let Cal Advocates and others address how the McCann critique affects the Cal Advocates analysis.[2] In this document, I address the extent to which the McCann critique applies to my April 2024 analysis. I find that the McCann critique makes fundamental conceptual errors that undermine most of its points and, with one exception, the critique does not change my analysis. The one exception results in a slight overestimate of the cost shift in my analysis. However, a number of other factors that McCann does not mention would cause my analysis to underestimate the cost shift, likely by a much greater amount.

---

[1] The linked spreadsheet has 31 tabs and no documentation. Some of it is understandable, but much of it requires a lot of speculation. The connection between the numbers asserted in the webpage and the spreadsheet is not made clear in most cases.

[2] The Cal Advocates response is available here. A detailed and thoughtful response on Bluesky from Xiao Wang is posted here. The $8.5 billion annual cost shift that Cal Advocates finds is much larger than my finding in part because (1) my analysis includes only residential customers with solar while Cal Advocates' includes all distributed solar, (2) their analysis uses a more recent figure for solar capacity, and (3) their analysis uses a higher average capacity factor for the panels. The CPUC (from which Cal Advocates operates independently) came to similar conclusions in a July 2024 report. The Utility Reform Network and Natural Resources Defense Council have also concluded that the annual cost shift is in the billions.

In summary, for California's three large investor-owned utilities, I still conclude that there is an annual cost shift of about $4 billion from residential customers who have adopted rooftop solar onto other customers.

Rates & Solar Output

The first point in McCann's critique is labeled "Rates & Solar Output". It first critiques the capacity factor used by Cal Advocates, nearly 20%, claiming that the appropriate capacity factor is actually 17.5%.[3] My analysis uses 17.2%, based on an earlier claim by CALSSA, so this critique is not relevant to my analysis. In fact, this aspect of my analysis would tend to understate the cost shift by about 1.8% compared to McCann's number, because I use an even lower capacity factor than the McCann critique claims is appropriate.

The second part of this point argues that Cal Advocates assumed none of the solar households were on the CARE program. My analysis does not make that assumption. It assumes that the shares of solar households on CARE in 2024 are 10% for SDG&E, 15% for PG&E and 16% for SCE, based on data from the CPUC. Furthermore, my analysis assumes that the output of solar systems on CARE homes is as high as those on non-CARE homes; in reality, CARE homes with solar almost certainly have smaller systems on average, so a lower share of the output than my analysis assumes is displacing payment at the CARE rate and a higher share at the standard retail rate. The assumption I made would therefore tend to understate the cost shift.

McCann's writing of the third part of this point is unclear, but it appears to argue that Cal Advocates overestimates the cost shift because it does not incorporate time-of-use rates in its calculation.[4] My analysis also does not incorporate time-of-use rates, but instead uses the average retail rates paid by non-CARE and CARE customers, analyzed separately, over all hours. This would tend to overstate the savings that solar households receive (and therefore overstate the cost shift) if the time-weighted average savings to owners from rooftop solar production under TOU (which is what McCann suggests that he uses) were lower than the time-weighted overall average rate paid by all residential customers (which is what I use). I was not able to find anywhere in McCann's spreadsheet where there was an adjustment for using TOU versus using the overall average rate, so it is difficult to know what numbers McCann used to make this adjustment.[5]

---

[3] McCann justifies this figure with a link to https://www.californiadgstats.ca.gov/charts/. This webpage, however, has no information on capacity factors.

[4] From McCann's critique: "The [Cal Advocates] miscalculates rates and overestimates solar output. Retail rates were calculated based on utilities' advice letters and proceeding workpapers. They incorporate time-of-use rates according to the hours when an average solar customer is actually using and exporting electricity." Given the calculations he makes, it appears that the second and third sentences refer to McCann's own analysis, though this is not going to win any awards for writing clarity.

[5] Searching on the terms "TOU", "time of use" and "time-of-use" did not locate their presence anywhere in the spreadsheet.

But a simple exercise suggests this would make very little difference. A calculation using the share of solar production that occurs during peak hours and the rate differential in PG&E territory suggest that doing the cost shift calculation with an average retail price overstates the cost shift by about 2%.[6]

However, there is a different way in which using the overall average retail rate biases the calculation towards *understating* the cost shift: The overall average retail rate includes the kWh sold at the discounted rate for baseline quantities (i.e., the lowest tier), which for PG&E is about $0.10 less than the rate for quantities above baseline. Thus, crowding out a kWh that is charged at the above-baseline rate saves the solar owner $0.10 more than crowding out a kWh that is part of the baseline quantity. Because NEM reduces the quantity for which a customer is charged, it disproportionately crowds out kWh that are charged at the full rate, increasing the savings for the customer relative to the overall average rate, and increasing the cost shift. According to Borenstein (2012), well over half of all kWh sold to all customers were on the lowest tier prior to significant use of rooftop solar. If 30% or less of the kWh crowded out by rooftop solar would have been on the lowest tier, then this would mean the average avoided payment is at least $0.02 higher than the overall average rate, likely more than offsetting the TOU effect and causing my calculation to understate the cost shift.[7] Later on the webpage, McCann claims that the typical solar home still pays an electricity bill of $80-$160 per month. If that is true, then a very small proportion of the kWh crowded out by their systems would have been charged at the baseline rate. That is, solar customers are avoiding higher tier rates on nearly all kWh that their systems displace, so using the average residential rate understates their reduced payments.

In sum, McCann's critique in this section has very little effect on my estimate of the cost shift, and adjustments would likely increase the estimate.

Self Generation

[6] PG&E's E-TOU-C has peak hours 4 PM-9 PM every day of the year. Its summer rates are $0.607 peak and $0.504 off-peak. Weighting these rates by CAISO system load shares (from 2015, when there was less than 3000 MW of rooftop solar capacity) during the summer months (May-September, 75.3% of load off peak) gives a weighted average rate of $0.529, while weighting those rates by the share of PV output (91.2% off-peak, based on NREL's PVwatts for Oakland) gives a weighted average rate of $0.513. For the winter months, the rates are $0.493 peak and $0.463 off-peak. Weighting those rates by CAISO system load shares during the winter months (October-April, 77.2% of load off-peak) gives a weighted average rate of $0.470, while weighting those rates by the share of PV output (95.4% off-peak) gives a weighted average rate of $0.464. Taking a year-round weighted average of the difference between the value under load-weighted and pv-output-weighted gives an average difference of $0.011. Thus, adjusting for TOU rates rather than using the revenue-equivalent time-invariant rate would reduce the cost shift by about one cent per kWh.

[7] McCann's calculations do not appear to adjust for the baseline consumption effect.

The Cal Advocates analysis and my own include a cost shift for the kilowatt-hours that customers "self-consume" from their solar generation. So long as a solar system is connected to the grid, there is no real distinction between self-consumption and grid supply. Despite this fact, if a customer's aggregate rooftop solar production during an hour is equal to the household's consumption, then some argue that the customer is "self-consuming" and their consumption in that hour should not be obligated to make any contribution to grid costs or other costs that are part of the retail price. McCann seems to be making this argument. However, if the customer does not have a battery, in any second of that hour, electricity is flowing in or out of the property and is using the grid. Thus, this argument conflicts with the basic physics of a solar home connected to the grid.[8]

Nonetheless, even if one accepts McCann's faulty argument, if one wishes to answer the question "how much higher are rates to residential customers because some have installed rooftop solar?" then the calculation should include electricity that is "self-consumed". My calculation answers this question. For every kilowatt-hour produced by rooftop solar, some cost of electricity from other sources is avoided and the cost of other grid services (such as resource adequacy and ancillary services) are also changed, which constitute the cost avoided by the system due to that rooftop solar production. I use an avoided cost based on the CPUC's avoided cost calculator that is created for this purpose. McCann rejects that avoided cost calculator and instead creates his own numbers that are drastically higher.

This critique by McCann misunderstands what the cost shift is measuring and relies on a confusion that perpetuates the myth that customers whose solar systems produce as much electricity as they consume over an hour (or a day, or a month) are not using the grid. No adjustment to my estimate of the cost shift is warranted
.

Historic Utility Savings

The McCann critique claims that distributed solar has displaced 15,000 megawatts of peak load and 23,000 gigawatt-hours of energy since 2006. The calculations behind these estimates are difficult to understand. While it claims that this measure is based on historic savings, the actual calculation seems to be based on one year of savings, which is appropriate. The McCann critique, however, claims that the 2024 rooftop solar capacity of approximately 15,000 MW displaces 15,000 MW of peak load. This completely ignores the fact that rooftop solar is producing nowhere near its full capacity during the hours of peak need, when most of that capacity value occurs, which is between 6 PM and 8 PM. The avoided cost calculator is designed to accurately value the capacity and energy cost savings that results from reduced customer demand in a given hour.

[8] Even if a customer has installed a battery, so long as they have not cut the cord and separated entirely from the grid, the utility has a duty to serve whatever demand they bring to the grid. Thus, the utility still needs to invest in transmission and distribution lines that would be adequate to serve them.

McCann rejects the avoided cost calculator and instead claims that absent 1 MW of rooftop solar capacity, 1 additional MW of combustion turbine capacity would have been needed in order to meet customer load. The 1:1 ratio drastically overstates the capacity value of rooftop solar today. Even grid scale solar produces only about 25% of its maximum output during 6-8pm, not 100%. The output of rooftop solar is much lower during 6-8pm, because rooftop solar is less likely to be efficiently oriented and is not built with trackers, which tilt the panels with the sun and capture more solar energy early in the morning and late in the evening. This is part of why the overall capacity factor of rooftop solar is in the range of 17.5%, while the overall capacity factor of grid scale solar is over 30%.

Furthermore, McCann's analysis that reaches the conclusion of 15,000 MW savings is based on the difference between the CEC 2005 forecast of 2024 load and actual peak load, and attributes the entire difference between the forecast and the peak load to rooftop solar. This confusion of correlation with causality is especially problematic given that so many other factors have obviously changed since 2005 (e.g., LED light bulbs, efficiency of air conditioning, rising electricity rates that have driven reduced consumption, among other factors), not to mention the high degree of uncertainty in forecasts of load a decade or two in the future. Moreover, even extrapolating the linear relationship McCann posits between the counterfactual peak load and the actual CAISO peak (52,061 on 9/6/22) out to 2024, the difference is less than 10,000 MW.[9]

The correct utility savings for 2024 would recognize that the output from rooftop solar reduces output from a variety of grid generation sources, and that mix of grid generation sources changes in different hours. Even at peak times, an additional MW of generation is generally not just displacing the need for a combustion turbine. The CPUC's Avoided Cost Calculator includes an analysis of what resources are avoided – for both energy generation and capacity – from reductions in net demand. The Avoided Cost Calculator accounts for the time at which the reductions are occuring. McCann's analysis ignores the fact that rooftop solar is producing very little electricity when the grid needs it most. Instead, he takes the most extreme, and completely unfounded, assumptions of what is avoided.[10]

---

[9] McCann may be suggesting that the peak stress on the grid (i.e., net load) occurring between 6 PM and 8 PM is a result of the high rooftop solar penetration. This is incorrect. On 9/6/22, the net peak occurred at 6:50pm, 47,337 MW. (See "Net Demand Trend" for 9/6/22 at https://www.caiso.com/todays-outlook.) At 1pm, presumably about the highest rooftop supply point (due to Daylight Saving Time), the net peak was 32,793 MW. At the time, the CAISO BA had about 12,000 MW of rooftop capacity (https://www.californiadgstats.ca.gov/charts/) So, even if all of that capacity were operating at 100% and it stopped displacing load, the net load in the middle of the day would have still been less than the net peak at 6:50 PM. The net peak demand would still occur between 6 PM and 8 PM due to the abundance of grid scale solar. Also see Xiao Wang's post on Bluesky for further discussion of McCann's capacity value calculation.

[10] Implicit in the McCann critique in this section, which he makes explicit in another blog post, is also a fundamental misunderstanding of the meaning of average cost and the relationship between average cost and marginal cost. McCann has a graph at the top of that post that has a standard marginal cost and average cost curve, but he omits a label on the horizontal axis. In this standard graph (which appears in any microeconomics textbook), the horizontal axis is not time, as he suggests in the discussion in the post, but rather quantity of output over a given

This critique of McCann's disregards the mismatch of the timing between when rooftop solar produces and when the grid is most constrained on generation, transmission, and distribution. The Avoided Cost Calculator is designed to capture those variations and has been closely scrutinized, while even a cursory look at McCann's calculations of the capacity and energy value show that they are obviously wrong. No adjustment to my estimate of the cost shift is warranted.

Displaced CARE Subsidy

Between the original posting of McCann's analysis and the version that is now on his website this value has been greatly reduced, which is a step in the right direction. But, in fact, it still greatly overstates this effect, which actually has the opposite sign than McCann claims.

McCann claims that other customers are made better off when a CARE customer generates their own electricity, because other customers then don't have to pay the subsidy that CARE customers get. But this argument misunderstands what saves other customers money, as well as the price that CARE customers pay relative to avoided cost. CARE customers are still paying well above avoided cost, and therefore are contributing to the system fixed costs. That contribution disappears when they generate from a rooftop solar system and get the NEM credit. Rates to other customers go up, not down, when a CARE customer generates electricity and gets NEM credit.

To give a numerical example, assume that the avoided cost is $0.10, the full retail price is $0.40, and the retail price paid by a care customer is $0.28. McCann argues that when a CARE customer generates from a solar system, they are saving other customers $0.12 that they are not getting as a discount from the full retail price. In fact they are costing other customers the $0.18 that they would have contributed towards fixed costs. CARE customers who have rooftop

---

period of time. It is, contrary to McCann's insistence, perfectly possible for average cost to rise over time without any change in marginal cost and without indicating that marginal cost is higher than average cost. That is exactly what happens when costs are added that do not change with the quantity consumed: subsidies for low income customers do not change the marginal cost of serving a different customer; above-market purchases of electricity in order to support a new technology impose an extra cost that raises average cost, but has no effect on marginal cost; the cost of hardening distribution lines is nearly entirely independent of how many kWh flows over that line so has almost no effect on marginal cost, but raises average cost. The statement in this blog post, "Yet PG&E's retail transmission rate component went from 1.469 cents per kWh in 2013 to 4.787 cents in 2022. By definition, the marginal cost must be higher than 4.8 cents (and likely much higher) to increase that much." demonstrates a complete lack of understanding of the concepts of average and marginal cost. Throughout his analysis of transmission and distribution costs, McCann erroneously relies on changes in average cost over time as an indicator of marginal cost.

solar are also shifting costs onto other customers, just not as much as customers who are not on CARE.[11]
This critique is premised on a fundamental misunderstanding of how customers contribute to the fixed costs of the system by paying a price that is greater than the incremental cost of the electricity they consume. The impact of CARE customers is accurately captured in my analysis. No adjustment in my calculation of the cost shift is warranted.

Customer Bill Payments

McCann points out that nearly all customers with solar still are net purchasers of electricity from the grid, which is correct. Therefore some of the cost shift is not shifted onto customers without solar but onto customers with solar through the kilowatt-hours they still purchase.[12] This is correct and I raised this point in the notes to my cost shift analysis linked to my April 2024 blog post. Some share of the cost shift is paid by the solar customers who are still buying net electricity from the utility.

However, this effect is very small. Assuming that 15% of households have solar and those households still buy 50% as much electricity from the grid as non-solar customers on average, those customers with solar would account for about 8% of residential retail sales and would incur about 8% of the burden from the cost shift. The other 92% of the cost shift would still be paid for by customers who do not have rooftop solar.

This critique is not relevant if one is asking how much higher rates are than they would be in the absence of rooftop solar (or, equivalently, if solar were paid its actual avoided cost). But it is relevant if one is asking which customers bear the burden of those higher rates. Nonetheless, over 90% of the cost shift is borne by customers who do not have solar.

Conclusion

Most of the arguments in McCann's critique are incorrect or simply do not apply to my analysis. The arguments that do apply to my analysis amount to very small adjustments in my estimate of the cost shift. In other parts of my analysis, I have made such conservative estimates that they almost certainly offset these adjustments. My conclusion remains that residential solar customers of the three large investor-owned utilities in California shift costs of about $4 billion per year onto other customers.

---

[11] Even if one accepted a greatly overstated avoided cost as McCann suggests, his calculation of the savings is fundamentally flawed. If the full retail price were $0.40, CARE customers paid $0.28 and the avoided cost were $0.30, then the savings to other customers would be $0.02, not $0.12 as McCann's argument suggests.
[12] It is worth noting, however, that this argument means that for most solar customers the marginal price of electricity they face is still the retail price. So the incredibly high retail price is discouraging electrification for even solar customers.

—----------

Epilogue

After I posted this reply to McCann, he posted a reply comment and then I posted a reply to his comment.

McCann Reply Comment: Here is my extended reply to Borenstein's critique of our analysis of the PAO's assertions about the cost shift. I note that Borenstein agrees that the PAO committed an error in using a capacity factor that is too high and by excluding CARE customers. He also acknowledges that the additional bill payments by NEM customers should be included in some manner. However, while calling for a fixed charge as the means of balancing out the cost shift, he ignores that we've calculated that NEM customers pay an amount toward fixed costs about equal to his calculation of what they should bear. He overlooks the strong legal precedents protecting self generation described in a law journal article by former FERC Chair Jon Wellinghoff and retired CPUC ALJ and current UCB law professor Steven Weissman. And I elaborate on why the Avoided Cost Calculator can only be used for forward looking evaluations and does not contain the information needed for evaluating historic investments.

https://mcubedecon.com/wp-content/uploads/2025/01/m.cubed-response-to-borenstein-critique-final.pdf

My Reply to McCann's Reply: There is so much misinformation in McCann's reply, both here and in his 11-page extended reply, that I am going to limit my comments to his post here and to the first few pages of his extended reply. There are many more mischaracterizations and misguided arguments that I would like to comment on, but I don't have time right now. I hope to put together a complete reply in the coming weeks. However, I have other responsibilities. For now,

1. Nothing that I wrote anywhere in my reply suggests that I think the PAO committed an error by using a higher capacity factor. The entire paragraph in which I discuss this topic is:

"The first point in McCann's critique is labeled "Rates & Solar Output". It first critiques the capacity factor used by Cal Advocates, nearly 20%, claiming that the appropriate capacity factor is actually 17.5%. My analysis uses 17.2%, based on an earlier claim by CALSSA, so this critique is not relevant to my analysis. In fact, this aspect of my analysis would tend to understate the cost shift by about 1.8% compared to McCann's number, because I use an even lower capacity factor than the McCann critique claims is appropriate."

In no way does anything in my reply suggest that the PAO number is incorrect. It simply says that I used an extremely conservative number, accepting the industry's claim. McCann's claim that I agree with him on this point is pure fiction.

1A. McCann claims that I made an error by characterizing the difference between 20% and 17.5% as a 1.8% difference. One would have to be pretty sloppy or completely uninterested in the truth to read the paragraph above and claim that the 1.8% I am referring to has anything to do with the difference between 20% and 17.5%. I don't think it could be made more clear that it refers to the difference between the 17.2% I used and the 17.5% McCann used. Sheesh!

2. On the payments by NEM customers, I said that this in no way changes my calculation of the counterfactual rate (if there were no cost shift), but it does affect who is paying that cost shift. My calculation suggests that less than 10% of the cost shift is paid by NEM customers. The other 90%+ is paid by customers without solar.

3. Actually, I have not called for a fixed charge as a means for balancing out the cost shift. I have called for moving many costs on to the state budget. As a backup if the legislature is unwilling to pay for the many costs they have added to the bill have I suggested a fixed charge, and in that case I have suggested an income-graduated fixed charge.

4. I do not overlook any legal opinions about self generation, because that is not what my analysis addresses. As is made explicit, my analysis addresses the question "how much higher are rates to residential customers because some have installed rooftop solar?". The opinions of Wellinghoff and Weissman are not relevant to answering that question.

5. It is completely inaccurate to claim, as McCann does in his reply, that I have "agreed, with caveats, that the rate reductions in subsidy savings for low income CARE customer should be included", presumably in the adjustment to a cost shift calculation. Rather, what I said was that McCann had analyzed the effect of CARE customers in a way that led him to conclude incorrectly that when a CARE customer gets solar other customers save money. His conclusion shows a basic misunderstanding of the concept of marginal cost.

6. McCann's claim about "historical utility savings" remains so muddled that it is difficult to respond to, but it seems that he is counting past benefits to the system (at a level alleged by McCann) as something that should be recognized in a calculation of the cost shift for 2024 while at the same time past cost shifts from solar owners onto other customers should be ignored.

7. McCann claims that the spreadsheet I posted in support of my cost shift calculations was "entirely undocumented". In reality, the way McCann got that spreadsheet was by downloading a zip file (https://faculty.haas.berkeley.edu/borenste/CostShiftBlogAppx240422.zip) that contains five files including a ReadMe.txt file that not only explains every variable in the spreadsheet, but also cites a source for every variable. The zip file also includes Stata code that generated the cost shift results. I'm not sure how he could have found his way to the spreadsheet and managed to not see all of the other information that came with it, and then ended up claiming that my work is undocumented.

8. McCann seems to be insulted by my reference to him as an industry consultant. His offense seems to be to the word “industry” since his retort is that he works for many different clients, many of whom are not in the solar industry. My point was only that he is paid to produce his analysis and come up with a conclusion that supports his client. That doesn’t mean his analysis is necessarily wrong, but it should be examined with extra scrutiny.

I am not compensated by anyone for this work, which is why I am going to end my reply here, rather than dig through the remaining 8-9 pages of misinformation that he has produced. If I have time in the coming weeks, I will post more on this, but I think it is pretty clear that his work is not a reliable representation of reality.

As I mentioned, this is not a complete reply to McCann’s last posting. It’s not even a complete response to all of the misinformation in the first few pages of his posting. I hope to update this when I get some more time.