Rooftop Solar Deployment, Potential Electricity Rate Impacts, and the Timing of Revisions to State Net Metering Policy

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NREL is a national laboratory of the U.S. Department of Energy
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Executive Summary

Most U.S. states require utilities to credit residential solar photovoltaic (PV) output at the retail electricity rate, a structure known as net metering. However, 12 states have replaced net metering with alternative rate structures that reduce PV adopter bill savings. According to our estimates, the share of households living in states that require net metering fell from around 84% in 2014 to around 57% by the end of 2023. Proponents of net metering revisions have argued that net metering can affect the electricity rates of customers without PV. This report analyzes the relationships between state PV deployment levels, potential electricity rate impacts on PV nonadopters, and the timing of revisions to net metering policy.

Prior research and our own estimates suggest the risk of rate impacts on PV nonadopters correlates with increasing residential PV deployment. We estimate, in all 30 states with a PV deployment rate below 3% of households, net metering is unlikely to be associated with an increase in rates of more than $1 per month per customer without PV. Among states with a PV deployment rate between 3% and 7% of households, we estimate that potential rate impacts are less than $1/month/customer in two-thirds of the states and $2–$6/month/customer in one-third of the states. Only two states—California and Hawaii—retained net metering above 7% PV deployment. In these states, we estimate potential rate impacts reached around $7/month/customer (Hawaii) to $19/month/customer (California), partly because of relatively high electricity rates and unique rate structure issues in these states. These estimates exclude the social and environmental impacts of rooftop PV, which do not directly affect electricity rates but could affect the perceived value of rooftop PV and of rate structures that enable its deployment.

Our analysis suggests the timing of net metering revisions has not consistently correlated with residential PV deployment levels or potential rate impacts. Of the 12 states that revised net metering, 9 did so when residential deployment was 3% or less and the potential rate impacts of net metering were likely less than $1/month/customer. Many states have retained net metering at substantially higher PV deployment levels with increased risk of potential rate impacts. At deployment above 10% and rate impacts around $5–$20/month/customer, the sample size is small—only California and Hawaii have reached these levels with net metering policies in place, and both subsequently revised their policies. These findings do not suggest a clear, consistent link between the potential rate impacts of net metering and revisions to state net metering policy. The timing and nature of net metering revisions are ultimately policy decisions based on balancing state-level priorities and considerations and the potential costs and benefits of different rate structures.

Table of Contents

List of Figures

1 Context

Rooftop solar photovoltaic (PV) systems allow electricity customers to reduce their use of and payments for grid electricity. Grid-connected rooftop PV systems can also export electricity to the grid. Forty-three states and Washington, DC, have required regulated utilities, at some point, to credit exported rooftop PV output at the same retail rate customers pay for grid electricity—a rate structure commonly known as net metering. Net metering is largely viewed as an administratively simple and acceptable default rate for residential PV adopters in nascent residential PV markets (Stanton 2019). Many states have also supported net metering as a measure to explicitly support residential PV adoption and achieve state clean energy goals (Peskoe 2016). Our calculations suggest that, before 2014, around 84% of U.S. households lived in states with statewide net metering requirements.[1] By ensuring that PV adopters realize long-term electricity bill savings from PV adoption, net metering has been a key enabler of residential PV adoption in the United States (National Academies 2023).

In recent years, some states and electricity regulators have replaced net metering with alternative compensation structures. Alternative structures implemented to date have reduced PV bill savings relative to net metering, and there is evidence that these rate revisions have curbed PV adoption in certain cases (Muro and Saha 2016; Gagnon et al. 2017; Barbose 2024). Proponents of these revisions have argued that net metering can increase the electricity rates of customers without PV. According to our estimates, by the end of 2023, the share of households living in net metering states had fallen to around 57%.

In this report, we analyze the relationships between state PV deployment levels, potential electricity rate impacts on PV nonadopters, and the timing of revisions to net metering policy. We do not explore the impacts of the revisions on electricity customers or on residential PV deployment levels.

[1] See Methodological Notes for further clarity on how we identified net metering requirements and revisions. The share of U.S. households is based on the revision timelines described in the Methodological Notes and estimates of numbers of households in U.S. Census American Community Survey data.

2 Trends in State-Level Net Metering Requirements and Revisions

By the end of 2024, 12 states that had previously required net metering had replaced net metering with an alternative structure, in which PV output is compensated at some rate other than the full retail electricity rate.[2] For simplicity, we refer to these changes as "revisions," though in some cases the changes are more substantial than may be implied by that term. The National Academies of Sciences, Engineering, and Medicine commissioned a study to explore net metering that summarizes the rate structures that have replaced net metering (National Academies 2023). See Figure 1-2 of that study for a complete description of those revisions. Briefly, most states have replaced net metering with some form of net billing, in which PV exported to the grid is credited at a unique rate, often determined by an estimation of avoided utility costs. Some states have implemented value-of-solar tariffs that credit self-consumed and exported PV output based on the estimated grid or societal value of that output. Further, net metering revisions often include adjustments to other aspects of PV adopter rate structures, such as increasing fixed charges or requiring PV adopters to switch to time-of-use rates.

Figure 1 depicts the distribution of PV deployment levels across states with varying net metering statuses, where PV deployment is defined in terms of the cumulative percentage of households that have adopted PV.[3] The figure shows that no states with deployment exceeding 10% of households have active net metering requirements. The figure also shows that three states revised net metering before less than 1% of households had adopted PV, whereas many other states have maintained net metering at PV deployment levels of 2%–7%. We explore the timelines of state net metering revisions in terms of rooftop PV deployment levels when revisions were implemented. As illustrated in Figure 2, five of the 12 states that have revised net metering did so before 1% of households had adopted PV, and 7 states did so before 3% of states had adopted PV. In contrast, California and Hawaii had PV deployment levels of about 14% when net metering was revised. Together, both figures show a lack of consistency with respect to the PV deployment level at which states have maintained or revised net metering.

[2] Illinois is scheduled to implement an alternative rate structure to replace net metering on January 1, 2025.
[3] PV deployment can be assessed in many ways. Another common approach is to calculate PV installed capacity as a share of the grid's total installed capacity. We explored alternative PV deployment metrics and found that the choice of metric does not significantly affect the core conclusions of this report.

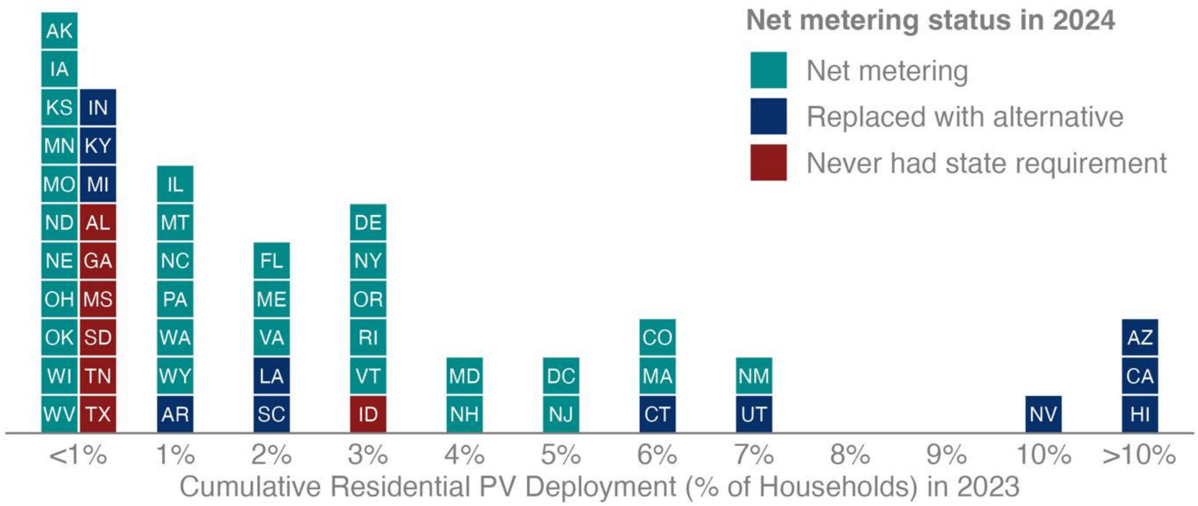

Figure 1. State-level net metering status and cumulative residential PV deployment levels.

See Methodological Notes for details and notes on the limitations of this figure.

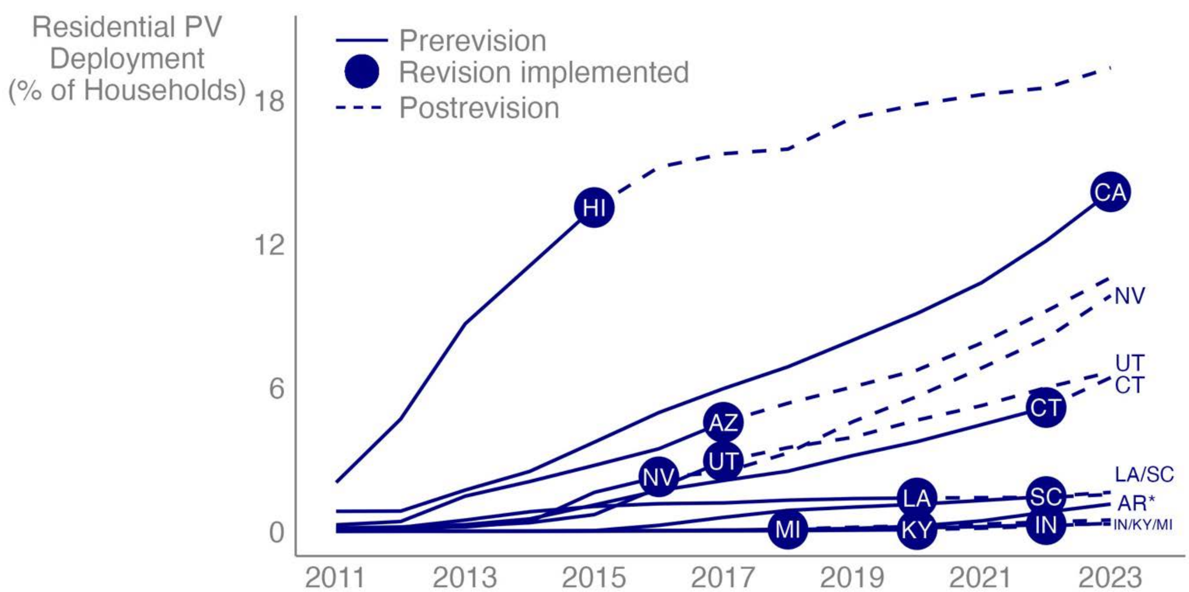

Figure 2. Cumulative residential PV deployment levels before and after net metering revisions.

See Methodological Notes for details and notes on the limitations of this figure. *Arkansas passed net metering revision legislation in 2023 and implemented the revision in September 2024.

3 Net Metering Issues

Electric utilities invest in grid infrastructure and operations to ensure a reliable electricity supply. Utilities recoup their investments by charging customers for grid electricity use. Public utility commissions regulate utility charges to ensure that utilities recoup enough revenues to cover all costs while preventing excessive profits. Importantly for this context, rate design requires reasonably accurate forecasting. Rate designers face the challenge of allocating utility costs across different groups of customers such that future revenues allow utilities to recoup approved costs and earn a regulated profit. Net metering may exacerbate this challenge by reducing future revenues recouped from rooftop PV adopters without proportionally reducing utilities' incurred costs. As a result, utilities may be unable to recover revenues for costs previously allocated to rooftop PV adopters (Kind 2013).

The impacts of rooftop PV on utility cost recovery can be mitigated and managed through rate design that effectively forecasts PV adoption and the changing use patterns of PV adopters (Rábago 2016). However, in practice, the under-recovery of forecasted revenues from PV adopters may cause rate designers to reallocate utility cost recovery among customer classes. Some stakeholders argue that this reallocation of costs increases the rates of customers without PV (Kind 2013).[4]

Whether net metering has materially affected the ability of utilities to recoup costs incurred to serve rooftop solar customers and whether those impacts have, in fact, affected electricity rates are open questions. Insofar as such impacts exist, there are also legal questions (outside the scope of this report) about whether the impacts merit revisions to net metering (Rule 2015; Peskoe 2016; Brooks et al. 2018; Rábago and Valova 2018). Still, numerous studies document theoretically plausible rate impacts from net metering in various contexts (Picciariello et al. 2015; Johnson et al. 2017; Boampong and Brown 2020; Borenstein et al. 2021). In the following section, we develop quantitative estimates of potential net metering rate impacts to explore the degree to which state net metering revisions correlate with such impacts.

[4] Potential shifts in cost allocations are often described as "cost shifts." We chose not to use this term because the under-recovery of revenues for costs *allocated* to PV adopters may or may not ultimately drive a cost shift in the sense that PV adopters do not pay for a service provided on their behalf. See Rábago (2016) for further discussion of this distinction.

4 Potential Net Metering Rate Impacts

We describe the potential rate impacts of net metering in terms of dollars per month per customer ($/month/customer), representing the potential increase in the monthly payments of customers without PV. We also present results in terms of percentage changes from typical customer bills. These metrics provide an estimate of the maximum impact of net metering on the monthly electricity bills of residential PV nonadopters if utilities reallocated all unrecovered costs to charges on customers without PV. However, the degree to which the under-recovery of revenues affects the rates of customers without PV depends on how underlying rate structures allocate costs across customers. Importantly, our estimates reflect the potential rate impacts that can arise as a result of mismatches in the electricity system costs and benefits of rooftop PV. Our method does not account for the broader social and environmental benefits of rooftop PV, because those values do not affect potential rate impacts. Still, the estimated social and environmental benefits of rooftop PV can be substantial. Analyses that include social and environmental benefits often conclude that the total benefits of rooftop PV exceed the costs (Muro and Saha 2016). Any potential impacts to net metering rates could potentially be justified as a means of achieving those social and environmental benefits.

Figure 3 illustrates estimated rate impacts across the 44 states (including Washington, DC) that have required net metering at some point (see Methodological Notes for details on the derivation of these estimates). The x-axis represents cumulative PV deployment at the end of 2023 for states that have maintained net metering or in the year in which revisions were implemented in the 12 states that revised net metering. The error bars represent 95% confidence intervals and reflect the high degree of uncertainty in the analysis. Positive rate impacts mean that net metering could plausibly increase the rates of customers without PV. Estimated ranges in six states reach below zero, representing cases in which estimated rate impacts could reduce the rates of customers without PV. Cases in which point estimates fall toward one extreme of the range reflect instances in which state- or utility-commissioned studies estimated relatively low values of solar (implying relatively large rate impacts) or relatively high values of solar (implying relatively small rate impacts). Figure 4 depicts estimated rate impacts leading up to net metering revisions following the same method.

The estimated potential rate impact is less than $1/month for a typical residential electricity customer in 38 of the 44 states, including 9 of the 12 states that have revised net metering. Such a rate impact is likely small relative to the impacts of other factors on residential electricity rates (Barbose 2017; see Methodological Notes). Point estimates for rate impacts are greater than $1/month in 6 states and greater than $5/month in 3 states: Connecticut ($6/month), Hawaii ($7/month), and California ($19/month). In relative terms, rate impacts are less than 1% of typical customer bills in 37 of the 44 states and greater than 2% in 4 states. The estimated impacts in California, Connecticut, and Hawaii amount to roughly 3%–15% of typical customer bills in those states. All three states offer bill assistance programs that partly insulate low-income customers from potential rate impacts. Figure 3 also suggests that California is an outlier, with exceptionally high estimated rate impacts associated with rate structure issues largely unique to that state (Borenstein et al. 2021).

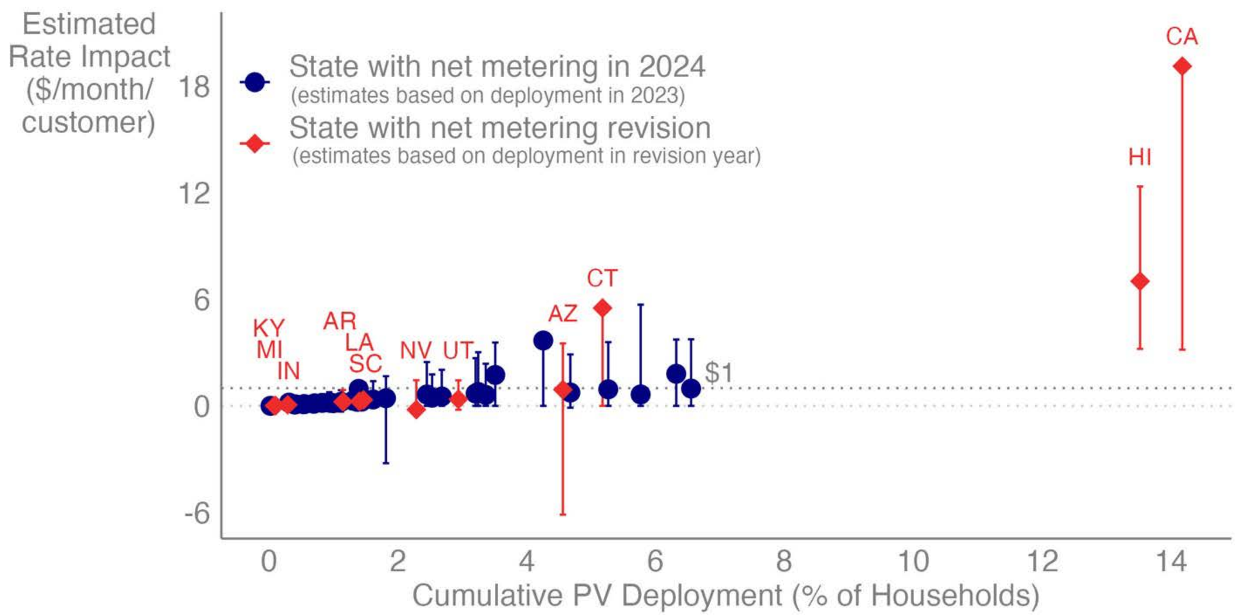

Figure 3. Estimated rate impacts ($/month/customer).

Figure reflects 44 states (including Washington, DC) that required net metering at some point. See Methodological Notes for details.

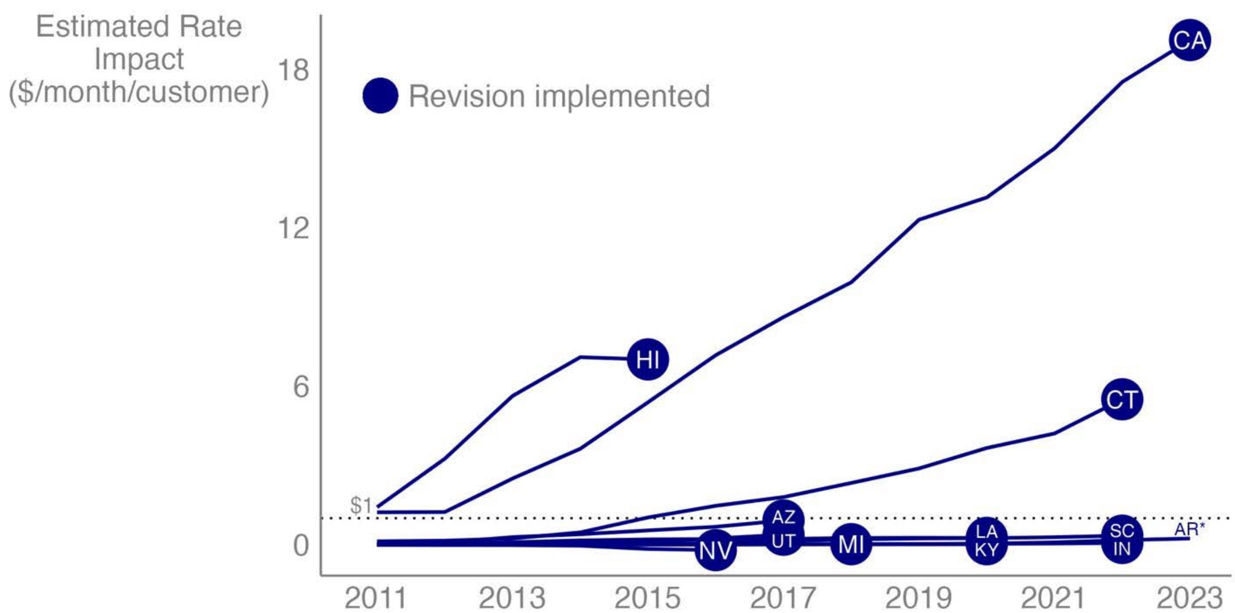

Figure 4. Estimated rate impacts leading up to net metering revisions.

Note the discontinuity in rate impacts in Hawaii from 2014 to 2015 is the result of a drop in the residential retail rate as reported by the U.S. Energy Information Administration (EIA). *Arkansas passed net metering revision legislation in 2023 and implemented the revision in September 2024.

5 Conclusions

Prior research and our own estimates suggest the risk of rate impacts on PV nonadopters correlates with increasing residential PV deployment. We estimate that, in all 30 states with PV deployment below 3% of households, net metering is unlikely to be associated with an impact of greater than $1/month/customer on the rates of customers without PV. Among states with PV deployment between 3% and 7% of households, we estimate that potential rate impacts are less than $1/month/customer in two-thirds of the states and $2–$6/month/customer in one-third of the states. Only two states—California and Hawaii—retained net metering above 7% PV deployment. In these states, we estimate that potential rate impacts reached around $7/month/customer (Hawaii) to $19/month/customer (California), partly because of relatively high electricity rates and unique rate structure issues in these states. These estimates exclude the social and environmental impacts of rooftop PV, which do not directly affect electricity rates but could affect the perceived value of rooftop PV and of rate structures that enable its deployment.

Our analysis suggests the timing of net metering revisions has not consistently correlated with residential PV deployment levels or potential rate impacts. Of the 12 states that revised net metering, 9 did so when residential deployment was 3% or less and the potential rate impacts of net metering were likely less than $1/month. Many states have retained net metering at substantially higher PV deployment levels with increased risk of potential rate impacts. At deployment above 10% and rate impacts around $5–$20/month (3%–15% of typical customer bills), the sample size is small—only California and Hawaii have reached these levels with net metering policies in place, and both subsequently revised their policies. These findings do not suggest a clear, consistent link between the potential rate impacts of net metering and state net metering revisions. The timing and nature of net metering revisions are ultimately policy decisions based on balancing state-level priorities and considerations and the potential costs and benefits of different rate structures.

6 Methodological Notes

Terminology: Net Metering and Net Metering Revisions

For the purposes of this report, net metering is defined as compensation for consumed and exported rooftop PV output at the full retail electricity rate. Net metering requirements refer to statewide mandates that require at least a subset of utilities to implement net metering. According to that definition, we identified 12 states that had once required net metering but subsequently implemented alternative compensation structures by the end of 2024. For simplicity, we refer to these alternative structures as "revisions." We excluded states that implemented revisions that affected solar compensation while retaining retail-rate net metering. Two notable examples include New York and North Carolina. In 2020, New York added capacity-based charges ($/kW of solar) for solar customers but retained full retail-rate compensation for PV output. Residential PV adopters in New York are also eligible to opt into a value-of-solar tariff as part of the state's Value of Distributed Energy Resources program. Given that New York residential customers are still defaulted into full retail-rate net metering as of 2024, we chose to treat New York as a state that has maintained net metering. In 2023, North Carolina added required fixed charges for solar customers but retained retail-rate net metering up to customers' monthly total consumption. Illinois is scheduled to become the 13th state to revise net metering with the scheduled implementation of an alternative structure on January 1, 2025.

Net Metering Revision Timeline

Our timeline of net metering revisions is based on our assessment of state net metering proceedings as documented in various sources, primarily the Database of State Incentives for Renewables & Efficiency, Apadula et al. (2024), and National Academies (2023). The exact timing and nature of net metering revisions are not always clear. For this reason, we implemented our analysis at an annual level to avoid depicting a false level of precision. Our analysis of net metering timelines should be understood as a good approximation of the relationship between key dates and PV deployment. PV deployment levels were estimated using annual net metering data from the Energy Information Administration (Form EIA-861M) and state-level household estimates from the U.S. Census Bureau.

Rate Impact Analysis

Barbose (2017) developed a simplified model to estimate the potential rate impacts of net metering. The model calculates rate impacts based on four parameters:

$$ri = d\left(\frac{r}{CoS} - \frac{VoS}{CoS}\right) \quad (1)$$

where *ri* is the rate impact in percentage terms, *d* is the cumulative PV deployment level (percentage of households), *r* is the retail rate at which PV output is compensated, *VoS* is the estimated value of solar (i.e., grid costs offset by PV output), and *CoS* is the average cost of service. Barbose's model usefully reduces the estimation of PV rate impacts into two key ratios: (1) the ratio of the retail rate to the *average* cost of service (*r/CoS*) and (2) the ratio of the value of solar to the cost of service (*VoS/CoS*). In theory, the retail rate *r* in a typical cost-based rate structure should roughly approximate the utility's average cost of service *CoS*. Under that assumption, Barbose simplifies the rate impact model to:

$$ri = d\left(1 - \frac{VoS}{CoS}\right) \quad (2)$$

With that simplification, the VoS/CoS ratio becomes the key parameter to determine the degree to which net metering drives rate impacts. As argued by Barbose, the VoS/CoS is highly uncertain and largely unknown. To build a distribution of VoS/CoS ratios, we infer VoS/CoS ratios from VoS studies and studies of net metering rate impacts:

- **Barbose (2017)** compiles VoS results and estimates 14 VoS/CoS ratios from state- and utility-level VoS reports commissioned before 2017.
- **Fine et al. (2018)** compile VoS estimates from three state-level studies. We extrapolated VoS/CoS ratios from those estimates based on EIA retail rate data for the years of the VoS estimates.
- **Other state-level studies:** We estimate VoS/CoS ratios using reported VoS estimates from five additional state-level studies not reflected in Barbose or Fine et al. from Connecticut (Connecticut Department of Energy and Environmental Protection 2020), Hawaii (Energy and Environmental Economics 2014), Maryland (Daymark Energy Advisors 2018), Montana (Navigant 2019), and New Hampshire (Dunsky Energy and Climate Advisors 2022).

In all cases, we use VoS/CoS ratios based only on utility costs and benefits—that is, excluding social and environmental benefits—to ensure that we accurately estimate the *rate* impacts of rooftop PV. From the process mentioned previously, we built a distribution of 22 VoS/CoS estimates as illustrated in Figure 5.

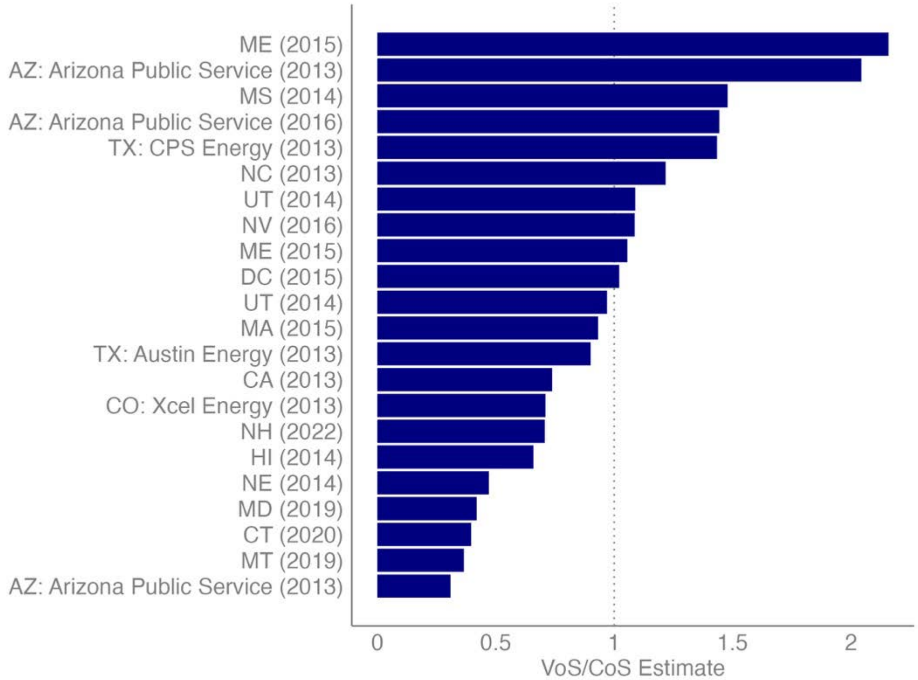

Figure 5. Distribution of VoS/CoS estimates from state- and utility-level VoS studies

We use the distribution depicted in Figure 5 to extrapolate VoS/CoS ratios across all states. In states with multiple VoS/CoS ratios from the literature, we use the average VoS/CoS ratio as a point estimate and the highest ratio as an upper-bound estimate (with the exceptions of California and Hawaii, discussed later). For states without state-level estimated ratios from the literature, we use the average VoS/CoS ratio across the 22 estimates weighted by the number of net-metered customers in each state in the year the VoS estimate was generated. To generate reasonable but conservative confidence intervals, we use a VoS/CoS ratio of 1 as an upper bound in all states without state-level VoS/CoS estimates from the literature. That is a conservative choice, considering that 10 of the 22 VoS studies imply a VoS/CoS ratio of greater than 1. In California and Hawaii—where previous VoS studies provide specific evidence of rate impacts—we use the weighted average VoS/CoS ratio described previously as the lower bound. As an upper bound we use a VoS/CoS ratio of 0.4 consistent with Barbose (2017), an assumption that is consistent with the lower end of the distribution in Figure 5.

California presents an exceptional case in many regards. California's residential rate structures are relatively complex, with rates that vary based on level of use and required time-of-use rates for recent PV adopters. Further, California utilities recoup an exceptionally large amount of fixed costs through volumetric ($/kWh) rates (Borenstein et al. 2021), creating cost distortions that reduce the utility of the simplified rate impact methodology provided by Barbose (2017). For these reasons, for California we rely on previous rate impact estimates rather than deriving those impacts from VoS/CoS ratios. Borenstein et al. (2021) estimate monthly rate impacts from net-metered PV in 2019 in California ranging from about $8 to $19 across the state's three major utilities. The PV adopter-weighted average of those estimates is about $12/month. Those rate impacts continued to increase into 2023 when California implemented legislation to eliminate net metering. Borenstein (2024) estimates that rate impacts increased to about \$0.10 to \$0.205/kWh across the three utilities, or an adopter-weighted average of about \$0.12/kWh. Extrapolating that figure to monthly payments using utility-level EIA data implies a monthly rate impact of about \$19/month. We used these two estimates—\$12/month and \$19/month—as point estimates for rate impacts in California in 2019 and 2023, and estimated rate impacts for the remaining years by using those estimates to back out a VoS/CoS ratio to implement into Equation (2).

Estimated Impacts of Energy Efficiency and Capital Expenditures

Barbose (2017) estimates that investments in energy efficiency affect customer electricity rates by around ±\$0.008/kWh, and that increasing utility capital expenditures (e.g., costs for transmission and distribution infrastructure upgrades, generation assets owned by utilities) could increase customer electricity rates by around \$0.016 to \$0.02/kWh. Adjusting those ranges to 2023 dollars and multiplying the rates by state-level average electricity use of residential customers in 2023 suggest that energy efficiency could affect customer electricity rates by around ±\$9/month on average across states, and that future increases in utility capital expenditures could affect customer rates by around \$17 to \$21/month. These figures provide imperfect benchmarks for assessing the potential rate impacts of net metering relative to other factors. The benchmarks are imperfect in that the potential rate impacts of other factors (e.g., energy efficiency) may not affect utility cost reallocation among customers in the same way as net metering potentially could. Still, this analysis supports Barbose's (2017) observation that "the effects of distributed solar on retail electricity prices are, and will continue to be, quite small compared to many other issues" (p. 31).

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