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Holland & Knight References (10 of 11)

The attached document is the tenth of 11 separate uploads that contain the references cited in Holland & Knight's DEIR Comment Letter.

Additional submitted attachment is included below.

A clean energy transition will require innovation in renewable energy technologies, but for these to achieve their transformative potential the institutions and systems that support existing fossil fuel regimes must be dismantled, a process known as exnovation[9]. Similar exnovation is needed to pave the way for change to other societal systems currently under scrutiny. The COVID-19 pandemic may prove to be the kind of large-scale disruption that expedites this process. Racial justice considerations must be front and centre as society starts to imagine what the new normal will look like, in the energy sector and beyond.

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U.S. NEWS SEPT. 13, 2018 / 9:44 PM

Census Bureau: California has highest poverty rate in U.S.

By Ray Downs

Sept. 13 (UPI) -- The poverty rate in California remains the highest in the nation, despite a small decline over the past year, according to U.S. Census Bureau data released Wednesday.

California's pov imated 19 percent this year -- a 1.4 percent decline from 2017. That comes out to approximately

The percentage is based on the supplemental poverty measure, which takes into accounts government programs to assist poor families. But despite California's many social programs, the state still has the highest poverty rate and experts say that a major reason is the high cost of housing.

"We do have a housing crisis in many parts of the state and our poverty rate is highest in Los Angeles County," Caroline Danielson, policy director at the Public Policy Institute of California, told The Sacramento Bee. "When you factor that in we struggle."

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And wages are not rising fast enough to keep up with housing costs, according to Sara Kimberlin, senior policy analyst at the nonprofit California Budget and Policy Center.

"A really key reason why California's poverty rate is so high is that we have very high housing costs in many parts of the state," Kimberlin told Capital Public Radio. "And even in areas of the state where housing costs are not as high, many people struggle with high housing cost burden."

The high cost of living in Los Angeles is a major reason why the homeles rate has increased 75 percent over the past six years, the Los Angeles Times reported.

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While high housing costs might be to blame for California's high poverty rate, several states in the top 10 have far lower costs of living, such as Louisiana (17.7 percent), Mississippi (15.9 percent) and New Mexico (15.2 percent).

Florida, where the cost of living in the Miami area is among the highest in the state, came in second with a 18.1 percent poverty rate.

A study last year found 45 percent of the population in Florida are working poor, with 6 out of 10 Miami residents struggling to get by.

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July 8 (UPI) -- More than a dozen states have dropped their objections to a bankruptcy plan by Purdue Pharma that would shift the OxyContin producer toward giving more money to help fight the opioid crisis in the United States.

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Tropical Storm Elsa hits North and South Carolina with heavy rains

July 8 (UPI) -- Tropical Storm Elsa is delivering "torrential rains" over North and South Carolina on Thursday as it moves across land and nears the Atlantic Ocean.

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Elsa kills 1 in Florida; injures 'multiple' at Georgia naval base

July 8 (UPI) -- Tropical Storm Elsa killed at least one person in Florida and injured several others in Georgia as the system made its way north across the southern states.

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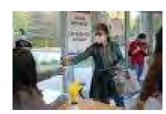

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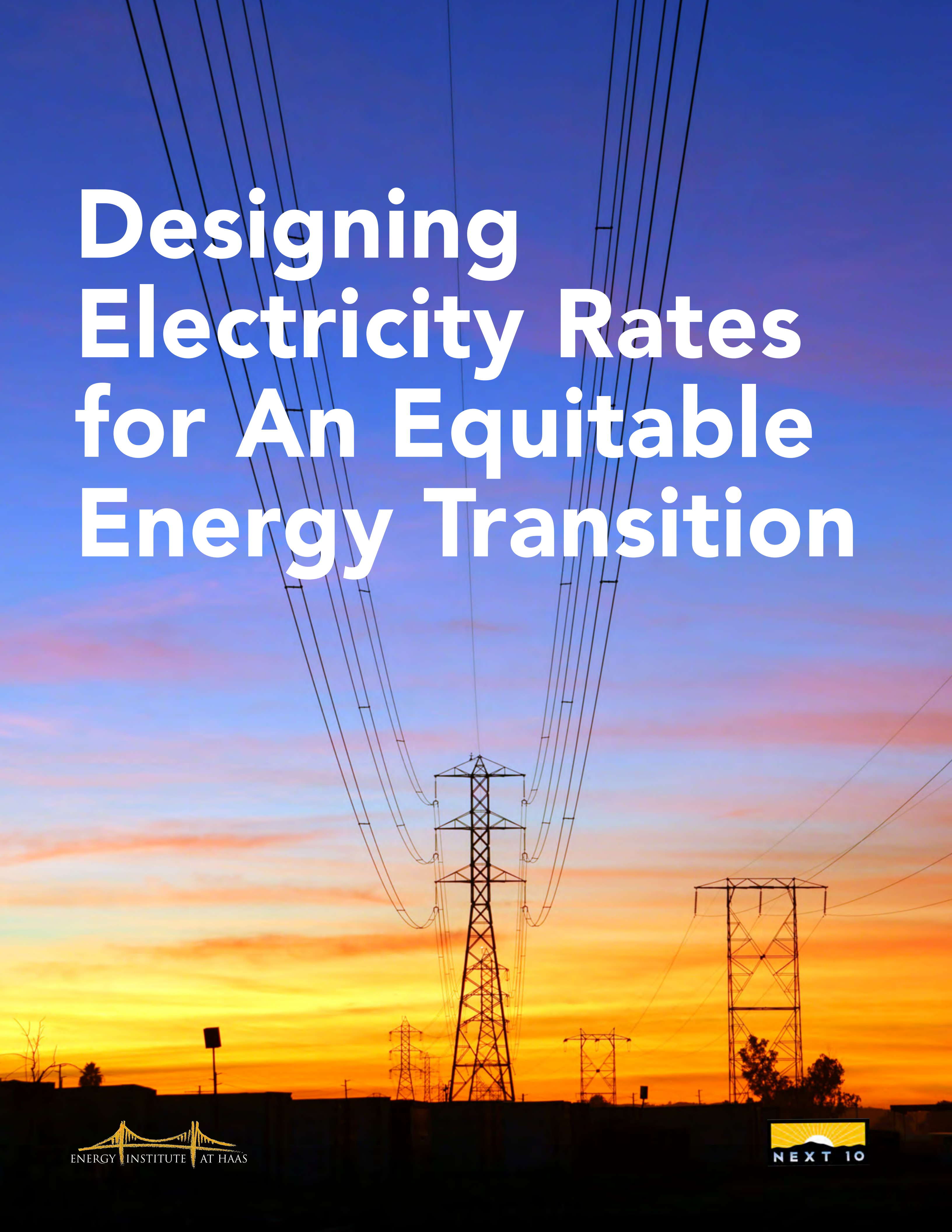
Designing Electricity Rates for An Equitable Energy Transition



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NEXT 10

Table of Contents

NEXT 10 is an independent nonpartisan organization that educates, engages and empowers Californians to improve the state's future.

Next 10 is focused on innovation and the intersection between the economy, the environment, and quality of life issues for all Californians. We provide critical data to help inform the state's efforts to grow the economy and reduce greenhouse gas emissions. Next 10 was founded in 2003 by businessman and philanthropist F. Noel Perry.

The Energy Institute at UC Berkeley's Haas School of Business helps create a more economically and environmentally sustainable energy future through research, teaching and policy engagement.

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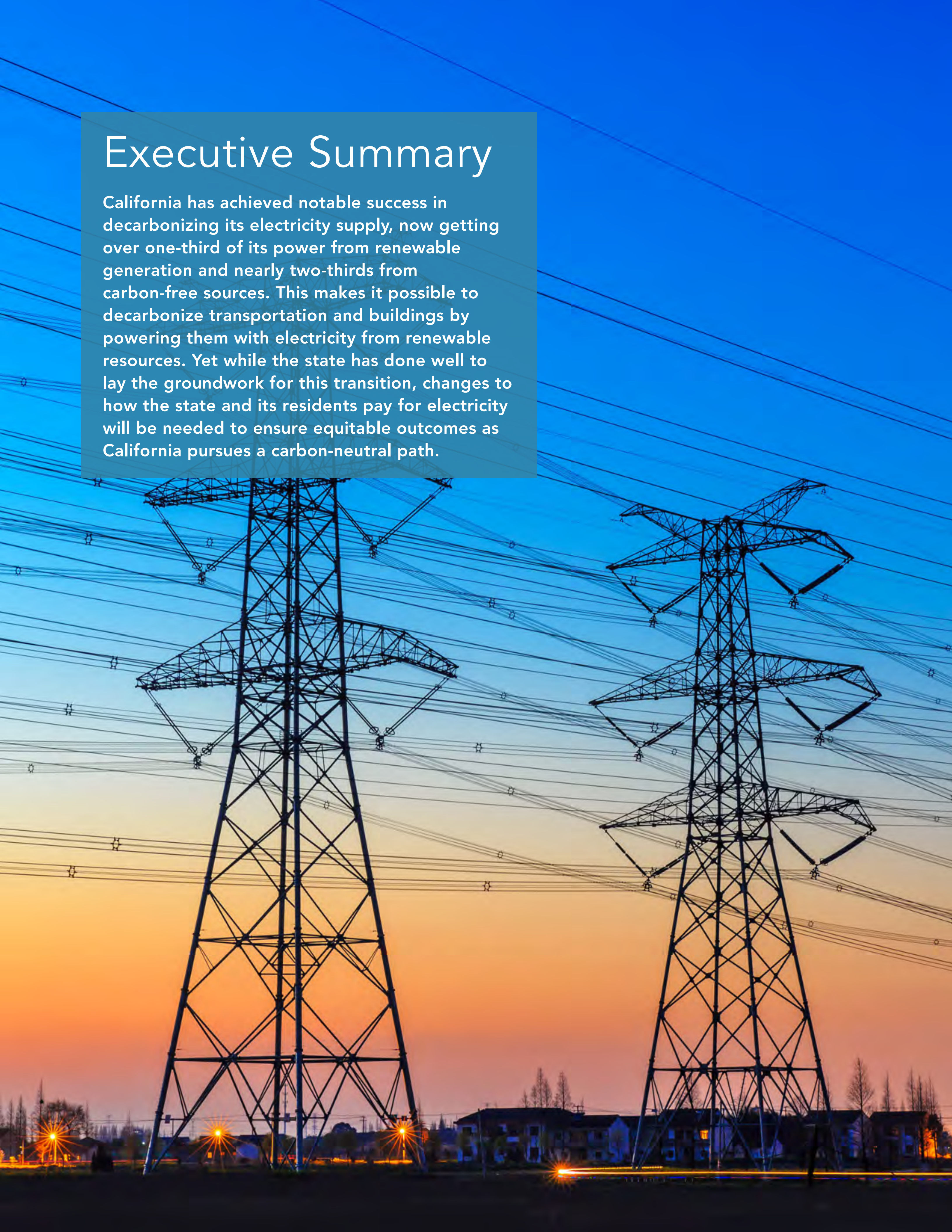
A PROJECT OF

For outstanding research assistance and very helpful comments, we thank Marshall Blundell.
For valuable comments and discussions, we thank Andy Campbell.

The Appendix can be found at https://www.next10.org/electricity-rates

Executive Summary

California has achieved notable success in decarbonizing its electricity supply, now getting over one-third of its power from renewable generation and nearly two-thirds from carbon-free sources. This makes it possible to decarbonize transportation and buildings by powering them with electricity from renewable resources. Yet while the state has done well to lay the groundwork for this transition, changes to how the state and its residents pay for electricity will be needed to ensure equitable outcomes as California pursues a carbon-neutral path.



Electricity prices in California are high and rising. This poses a heavy burden for many of the state's most economically vulnerable households. It is also a headwind in the state's efforts to combat climate change through electrifying transportation and buildings, which many see as critical steps to a low-carbon future.

The state's three large investor-owned electric utilities (IOUs) recover substantial fixed costs through increased per-kilowatt hour ("volumetric") prices. With nearly all fixed and sunk costs recovered through such volumetric prices, the price customers pay when they turn their lights on for an extra hour is now two to three times what it actually costs to provide that extra electricity—even when including the societal cost of pollution. This massive gap between retail price and marginal cost creates incentives that inefficiently discourage electricity consumption, even though greater electrification will reduce pollution and greenhouse gas emissions. Changing the way that electricity is paid for can address this issue.

This report takes stock of the current situation facing residential customers of California's large electricity IOUs and describes pricing reforms that could improve economic efficiency, facilitate decarbonization, and improve overall equity. The analysis includes several findings that are pertinent to ongoing conversations about affordability, decarbonization, rooftop solar, and wildfire mitigation, including:.

- **California IOUs' prices are high, by both historical and national standards.** A look at national data from the Federal Energy Regulatory Commission (FERC) shows that the average price of residential electricity in California's three large IOUs is out of line with the rest of the country. In the least expensive territory, Southern California Edison (SCE), residential prices per kilowatt hour are about 45 percent higher than the national average. Prices for Pacific Gas & Electric (PG&E) are about 80 percent higher, and prices in San Diego Gas & Electric (SDG&E) are roughly double the national average.
- **These high prices are two to three times the cost of producing additional electricity.** To reach this conclusion, this report analyzed the marginal cost of electricity—that is, the increase in cost incurred in order to deliver additional kilowatt-hours of electricity to an existing customer—and compared that cost to current rates. The authors found that the price of electricity ranged from double to triple the marginal cost in 2019. Even low-income customers who receive a subsidized rate paid prices well above marginal cost. The misalignment between price and cost creates problematic incentives.
- **High prices are driven in part by a shifting burden of fixed cost recovery.** Currently, 66 to 77 percent of the costs that California IOUs recover from ratepayers are associated with fixed costs of operation that do not change when a customer increases consumption. This includes much of the costs of generation, transmission and distribution of electricity, as well as subsidies for low-income household and public purpose programs, such as energy efficiency assistance. In addition, greater adoption of behind-the-meter (BTM) solar photovoltaic (PV) panels—which represented more than 15 percent of the residential electricity consumption across the PG&E, SCE, and SDG&E service territories in 2019—has disproportionately shifted cost recovery onto non-solar customers adopters.
- **Lower- and average-income households bear a greater burden.** These households are increasingly having to cover high fixed costs from a shrinking base as wealthier customers leave for rooftop solar. Higher-income households now consume only modestly more electricity than lower-income households.[1]
- **More equitable alternatives can be found and implemented.** The report authors detail a variety of potential approaches to ensure utility revenues can be kept stable without relying on the current regressive rate model as the state looks to increase electrification.

1 Borenstein (2017) finds that for customers in PG&E territory, households in the top 40% of income were more than twice as likely to install solar PV as households in the bottom 60%. Using a different statistical approach and data through 2016, Barbose et al (2018) find that the median income of California households installing solar PV was more than 40% above the median income of households overall. The next stage of the current research project will update analysis of this income gap. Borenstein available at: https://www.journals.uchicago.edu/doi/abs/10.1086/691978. Barbose et al available at: https://emp.lbl.gov/publications/income-trends-residential-pv-adopters

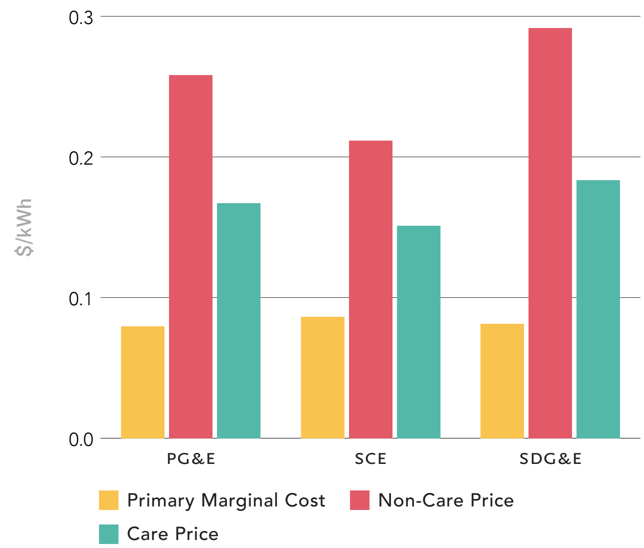
- **The report suggests the following alternatives for paying the cost of electricity in the state:**
    - » Tax revenue: Raising revenue from sales or income taxes would be much more progressive than the current system, ensuring that higher-income households pay a higher share of the costs.
    - » Income-based fixed charge: A more politically feasible option could be rate reform—moving utilities to an income-based fixed charge that would allow recovery of long-term capital costs, while ensuring all those who use the system contribute to it. To make a fixed charge equitable, it would be based on income. In this model, wealthier households would pay a higher monthly fee in line with their income.
        - · The report offers several ways to structure an income-based fixed charge, based on three criteria: set prices as close to cost as possible; recover the full system cost; and distribute the burden of cost recovery fairly.
- **Wildfire cost transparency.** Finally, the report identified the need for more transparent accounting of wildfire mitigation costs, as the authors could not obtain clear wildfire-related expenditure data. This is vital as wildfire mitigation costs are likely to be a major driver of price increases in the near future.[2]

More detail on these findings can be found below and in the body of the report.

Retail Prices Vs. Marginal Cost

The report's estimate of the marginal cost of electricity includes not only the cost of generating additional electricity, but also potential increases in costs for transmission and distribution capacity that scale with usage, as well as the potential need for additional generation capacity. The cost of greenhouse gas (GHG) emissions is also included, which is borne by society rather than the utilities to the extent that existing programs (e.g., cap and trade) only partially price this climate externality. There is no perfect way to calculate all of these costs with the available data, so a variety of alternatives is presented in the Appendix. In all cases, the marginal cost is vastly lower than current rates.

FIG ES-1 Residential Retail Prices Vs. Social Marginal Cost ($/kWh) for 2019



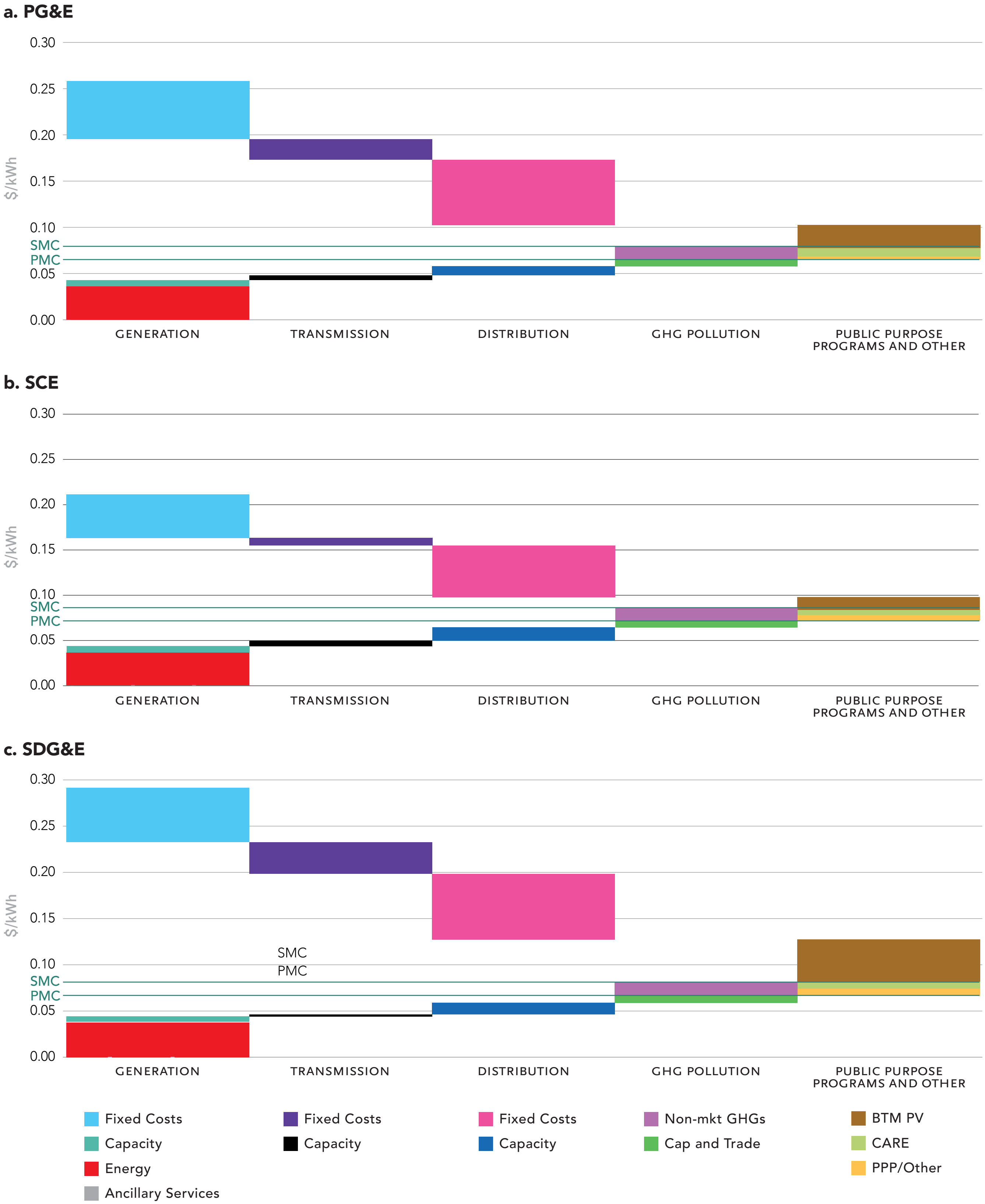
Note: Primary marginal cost estimates are weighted by IOU load. Average 2019 residential prices (CARE and non-CARE) are constructed using advice letters and rate schedules. PG&E sources: 5366-E-A/B; 5444-E; 5573-E; 5644-E. SCE sources: 67666-E: 67668-E. SDGE: 31811-E; 31501-E. Details on the methodology behind author calculations can be found in the Appendix.

The authors' primary estimate of marginal cost for 2019 is shown in Figure ES-1, along with estimates of the average residential price of electricity for each IOU. The price of electricity is more than double the estimated marginal cost for SCE, and it is more than triple for PG&E and SDG&E. Over 25 percent of residential customers in California pay lower rates through the low-income program, California Alternative Rates for Energy (CARE), but report authors found that even CARE rates are substantially above marginal cost, as shown in the figure.

This finding is not a commentary on the appropriateness of overall costs. High total system costs in California may well be justified by conditions in the state. Rather, the implication of this finding is that by recovering total system costs through high volumetric prices, California's IOUs are now operating a pricing scheme that sends misleading signals about the true cost to society of consuming electricity. Pricing reform that aligns the volumetric price of energy with marginal cost would dramatically reduce prices, which has the potential to spur electrification of other sectors of the economy.

2 Balaraman, Kavya. "California IOUs plan to spend $11B on wildfire prevention in 2021 and 2022 after record-breaking fire season." Utility Dive. February 9, 2021. Available at: https://www.utilitydive.com/news/california-ious-plan-to-spend-11b-on-wildfire-prevention-in-2021-and-2022/594823/

FIG ES-2a-c Residential Price Decomposition ($/kWh) for 2019



Note: Details on data sources and methodology behind authors' calculations can be found in the Appendix.

Components of California Electricity Rates

The components of California's high electricity rates are unpacked in detail in this report and are summarized for each utility in Figure ES-2a-c, which breaks down the average volumetric price facing a residential customer on a standard rate. This figure decomposes costs into five main categories: generation, transmission, distribution, pollution and a residual category that combines public purpose programs and other costs. For generation, transmission and distribution, the costs are separated into the component that is part of marginal cost and the remaining costs that do not scale with usage. Details of each item's calculation is included in the report.

The marginal cost components are added up in the bottom staircase. Marginal cost is the combined height of the boxes representing the marginal costs of generation, transmission, distribution and greenhouse gas emissions that are associated with producing an additional unit of electricity. This is labeled here as the private marginal cost (PMC). Adding the unpriced portion of pollution damages resulting from electricity yields the social marginal cost (SMC). The other boxes represent additional system costs that do not scale with usage. These are all costs that are being recovered through high volumetric prices for standard rate customers, but they represent fixed costs that range from regular maintenance to wildfire mitigation to cross-subsidies for CARE customers and rooftop solar.

A few findings are apparent from the figure. First, the additional system costs are spread across several factors that, taken together, drive the high cost. In particular, costs associated with generation and distribution comprise a significant share of the cost recovery gap.

Second, as more and more households adopt behind-the-meter (BTM) solar photovoltaic (PV) panels, cost recovery is disproportionately shifted onto the bills of solar non-adopters. In 2019, the report authors estimate that behind the meter residential solar production supplied more than 15 percent of the residential electricity consumption across the PG&E, SCE, and SDG&E service territories. The fixed costs recovered via high volumetric electricity prices are shifted—not avoided—when a residential customer installs rooftop solar. In other words, as residential solar adoption increases, system costs are being recovered from a shrinking base.

An additional finding of the report's cost component analysis is that there is great need for a more transparent accounting of wildfire mitigation costs that could inform public debate. Despite going to considerable lengths in an attempt to delineate wildfire-related expenditures by separating them from other costs with publicly available data, it was not possible for the report authors to get clear numbers. In Figure ES-2-a-c, these costs are embedded primarily in transmission, distribution and other fixed costs. Wildfire mitigation costs are likely to be a major driver of price increases in the near future. Wildfire mitigation is a statewide priority that delivers benefits to households throughout all utility territories, regardless of the quantity of electricity they consume, suggesting that perhaps some associated costs should be borne by the state at large. Transparent and consistent data about associated costs is essential to inform decision-making about how to pay for wildfire mitigation.

Improving Equitable Pricing of Electricity

A key finding of the report's analysis is that the current system of recovering system costs through high volumetric prices is not only inefficient; it is also far less equitable than viable alternatives. It imposes a relatively large burden on lower- and average-income households while it recovers a shrinking fraction of system costs from higher-income households because of the diffusion of rooftop solar.

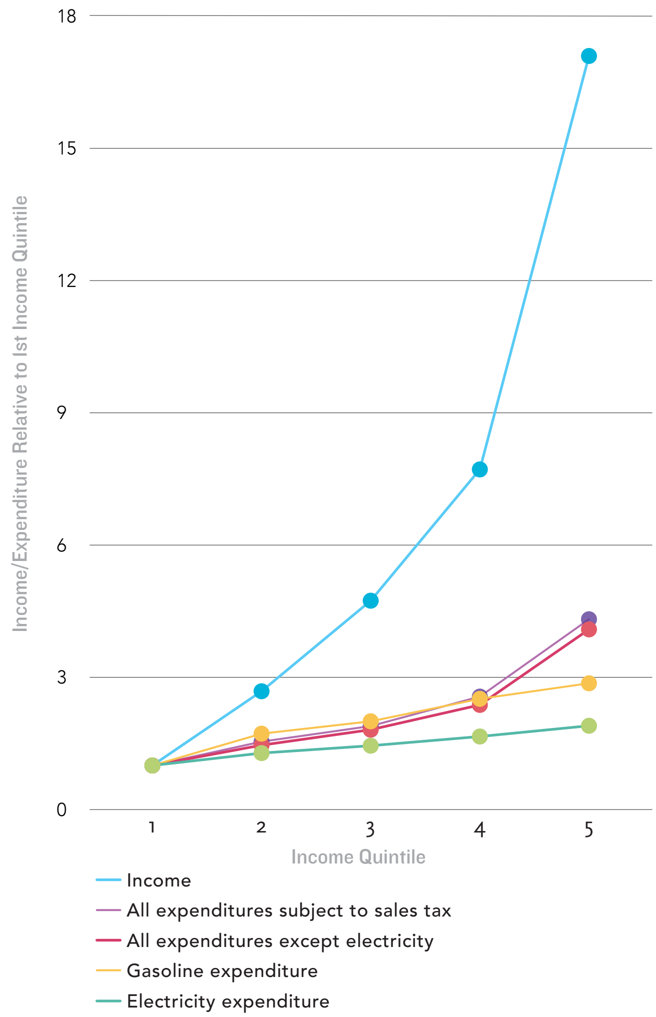
The authors are in the process of constructing a detailed assessment of how the burden of cost recovery is allocated across households in the current rate system, but that analysis involves customer billing data that was not obtained in time for this report. While a forthcoming Next 10-Energy Institute study will incorporate customer billing data, this initial report relied on survey data about household expenditures in California from the US Bureau of Labor Statistics, which are presented in Figure ES-3. Those data show that higher-income households spend only modestly more on electricity than lower-income households, a much smaller differential relative to differences in incomes or expenditures on most other goods, including even gasoline.

Alternative Funding Mechanisms to Ensure an Equitable Electrification Transition

To address these inefficiencies and ensure a more equitable path toward greater electrification, the state could potentially support some measures, such as public purpose programs or wildfire mitigation, directly through other tax revenue. Analysis of the survey data from the US Bureau of Labor Statistics (BLS) suggests that using revenue raised from sales or income taxes would be much more progressive than the current scheme of covering residual costs above marginal cost by increasing volumetric electricity prices. This is apparent in Figure ES-3, which shows that expenditures on goods subject to the sales tax rise much more steeply across the income distribution. Thus, raising electricity system revenue through the sales tax would recover far more of the costs from richer households than does the current scheme. The distribution of income rises even faster than do taxable expenditures—which means that paying for some system costs through additional revenue raised via the income tax in California would be even more progressive.

Recognizing potential political barriers to leveraging state revenue to pay for electricity system costs, the report also considered ways of reforming the electricity system that could align prices with marginal cost without imposing an additional burden on those least able to afford it. To that end, a final key finding is that an income-based fixed monthly connection charge could raise revenue to cover utility costs while maintaining a volumetric price that reflects marginal cost and improving equity outcomes. This fixed monthly charge would require income verification, but would ultimately help reduce volumetric rates while providing stable revenue to utilities. The report concludes by discussing the possible structure of an income-based fixed charge, including some possible rate structures, as well as some of the logistical and equity considerations and trade-offs that would need to be weighed in order to implement such a scheme.

FIG ES-3 Average Expenditures and Income per California Household by Income Quintile Relative to Lowest Quintile



Source: Authors' calculations of data from the Consumer Expenditure Survey in 2017-2018. Source data at https://www.bls.gov/cex/2017/research/income-ca.htm

1. Introduction

California has charted an ambitious course towards decarbonizing its economy. The state achieved its 2020 goal of reducing GHG emissions to 1990 levels four years early. Notably, almost all of these emissions reductions have been achieved in the electricity sector. At the same time, California has among the highest electricity prices in the continental U.S. These two facts create a tension: decarbonizing the economy most likely requires electrification of transportation and space and water heating, but high prices push against such a transition. High prices also have troubling implications for equity and affordability. If the costs of decarbonizing the power sector are recovered through higher electricity prices, this could impose a large economic burden on low-income households amidst an increasingly unequal economy. This report discusses the causes and consequences of California's high residential electricity prices, and it evaluates the merits of several potential remedies.

This study begins by asking why the residential electricity prices charged by California's investor-owned utilities (IOUs) are so high. First, the avoidable—or marginal—cost of providing additional kilowatt-hours (kWh) of electricity to a residential customer are identified. This is a necessary first step because, to the extent that high electricity prices actually reflect high incremental costs of generating and delivering electricity, high prices are economically efficient. If that is the case, then high prices are still problematic, but they can only be addressed in an economically- efficient manner by policies that lower marginal costs.

Instead, the authors find that residential electricity prices of California's IOUs are two to three times higher than social marginal costs (SMC), that is, marginal cost inclusive of environmental externalities. Marginal cost estimates from this study are consistent with prior work, such as analysis commissioned by the California Public Utilities Commission and other recent studies.[3] This conclusion is based on building an estimate of the social marginal cost of electricity that accounts for the direct cost of additional generation, the social cost of associated pollution, line losses from transporting the electricity, and appropriate capacity costs in generation, transmission and distribution that might change with demand. Section 3 provides a detailed discussion of the marginal cost estimates.

If a utility charges a retail electricity price equal to social marginal cost, this sends an economically-efficient price signal to consumers, but it would probably not collect enough revenue to cover all of the costs of the grid, as well as other priorities that are currently supported via volumetric (i.e., per-kWh) rates. The cost recovery gap is defined here as the difference between a utility's current revenue and the revenue it would collect if it instead charged the economically-efficient social marginal cost for the same quantity. This study estimates that gap and then decomposes it into a set of factors that increase the utilities' revenue requirements.

Broadly, these factors can be divided into three classes. One class includes costs that are currently funded through rates but are not required to serve current load. Energy efficiency programs are an example, as are funds that support new low-carbon technologies. A second class includes costs that are necessary for the maintenance of the grid but would not change if demand from current customers increased or decreased over a substantial range. An example is the maintenance of existing transmission lines. A third class includes cross-subsidies among rate payers. These include incentives for rooftop solar and rate discounts for low-income customers provided via the California Alternative Rates for Energy (CARE) Program.

The authors conclude that California's residential energy prices are high not because of any one factor, but because of the cumulative effect of many of these cost drivers. That said, some factors are larger than others. The role of energy efficiency programs and the Renewables Portfolio Standard (RPS) has waned in recent years, whereas the impact of rooftop solar subsidies is large and rapidly growing. The majority of the cost recovery gap is related to recovering fixed costs for the grid, which are projected to grow further as a result of wildfire mitigation and other factors. Details of the calculations for recent years are in Section 5.

Who bears the burden of fixed cost recovery under the current rate design? A detailed analysis of how costs are allocated across households requires utility billing data, which the authors of this report are in the process of acquiring, in anonymized form. For this initial report, however, the authors present preliminary analysis using the Consumer Expenditure Survey from the US Bureau of Labor Statistics. That analysis suggests that the current approach to cost recovery by increasing volumetric rates—essentially a volumetric tax—is quite regressive.

Unfortunately, the state budget is under considerable pressure, which makes it less likely that costs can be moved from electricity rates to the general fund. Therefore, this report explores an alternative that keeps cost recovery within electricity rates, but reduces regressivity. The starting point is to introduce a substantial fixed charge that would enable the utilities to lower volumetric prices towards avoidable cost. This would enhance economic efficiency and foster greater electrification, while keeping utility revenue stable.

3 Borenstein, S. and Bushnell, J. "Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency." Energy Institute at Hass. July 2019. Available at: https://haas.berkeley.edu/wp-content/uploads/WP294.pdf. Detailed documentation of CPUC commissioned estimates of the avoided costs of distributed energy resources can be found at: https://www.ethree.com/public proceedings/energy-efficiency-calculator/

The primary objection to fixed charges is that they tend to be regressive. A move to uniform fixed charges that apply equally to all households would likely exacerbate the inequities in the current system. Instead, this report proposes a system of fixed charges that are based on a sliding scale of income, so that lower-income households pay a lower monthly connection fee. In terms of administration, it may not be advisable for the utilities themselves to determine the income of households, and so instead the authors propose that this system be implemented in coordination with the state's income tax authority, the Franchise Tax Board. Coordination between the utilities and the state could come in a variety of forms. Discussion of the strengths and weaknesses of several versions of this idea, as well as several potential rate structures, are in Section 7.

This report is a preliminary analysis in an ongoing research program. Going forward, the report authors plan to use anonymized customer billing records to characterize in much more detail the distributional burden of the current model of cost recovery and these alternatives. The potential impact of high volumetric rates on the goals of decarbonizing residential buildings and personal transportation will also be analyzed as part of a follow-on study to be released later this year.

2. California's Rates are Among the Highest in the Country

This report's analysis begins with an overview of California's residential retail prices. Figure 1 displays the average residential electricity price for the three California IOUs and a box-and-whiskers plot of the distribution of average residential electricity prices across US utilities, based on data from the Federal Energy Regulatory Commission (FERC). For each year, the solid horizontal line shows the national average (median) price (weighted across utilities by load), and the box traces the 25th to 75th percentiles. The lines (whiskers) extending from the box show the 5th and 95th percentiles. These data reveal that SDG&E and PG&E rates are now among the top few percentile of all residential rates in the country. SDG&E's rates are double the national median. SCE's rates are lower, but still about 45 percent above the national median.

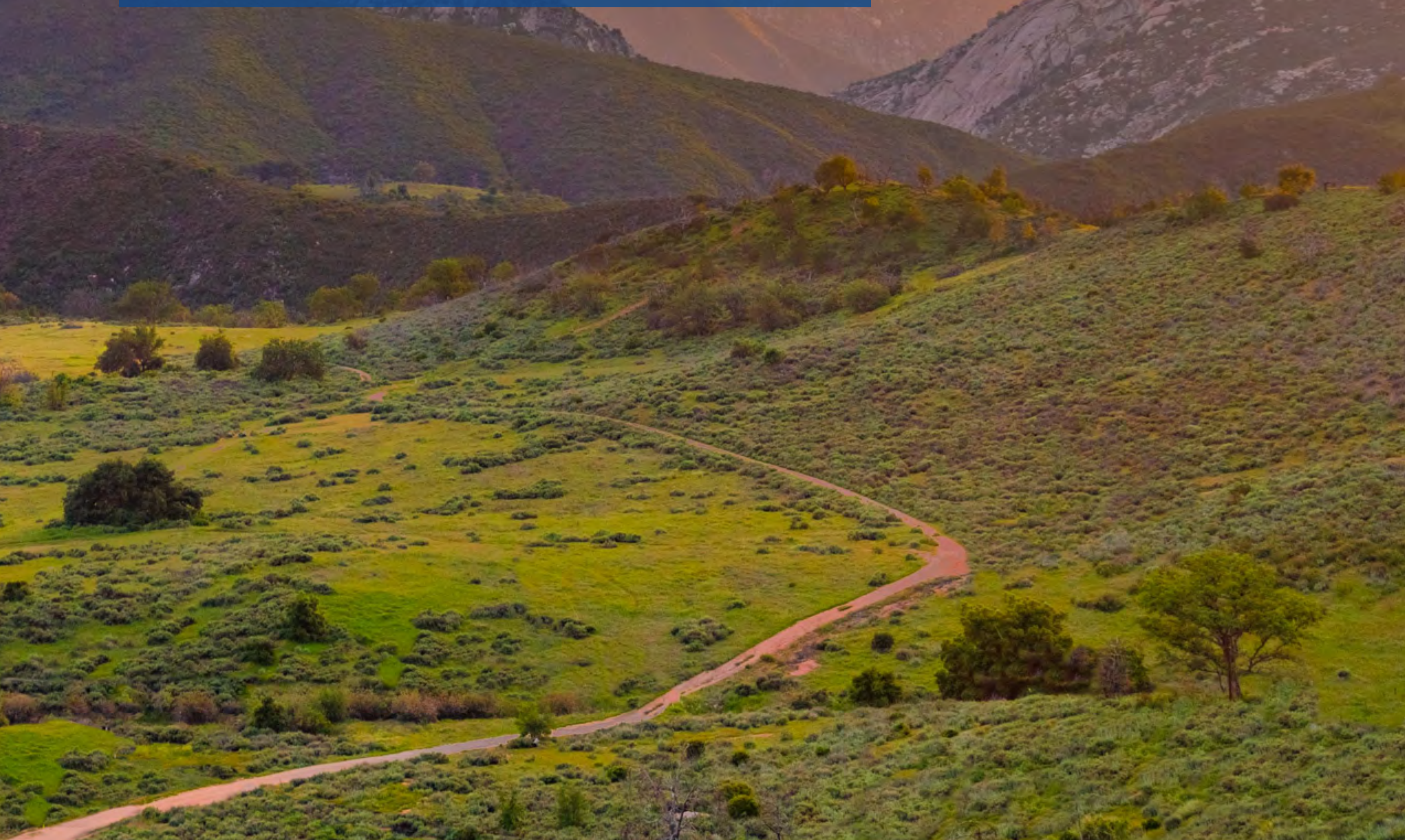
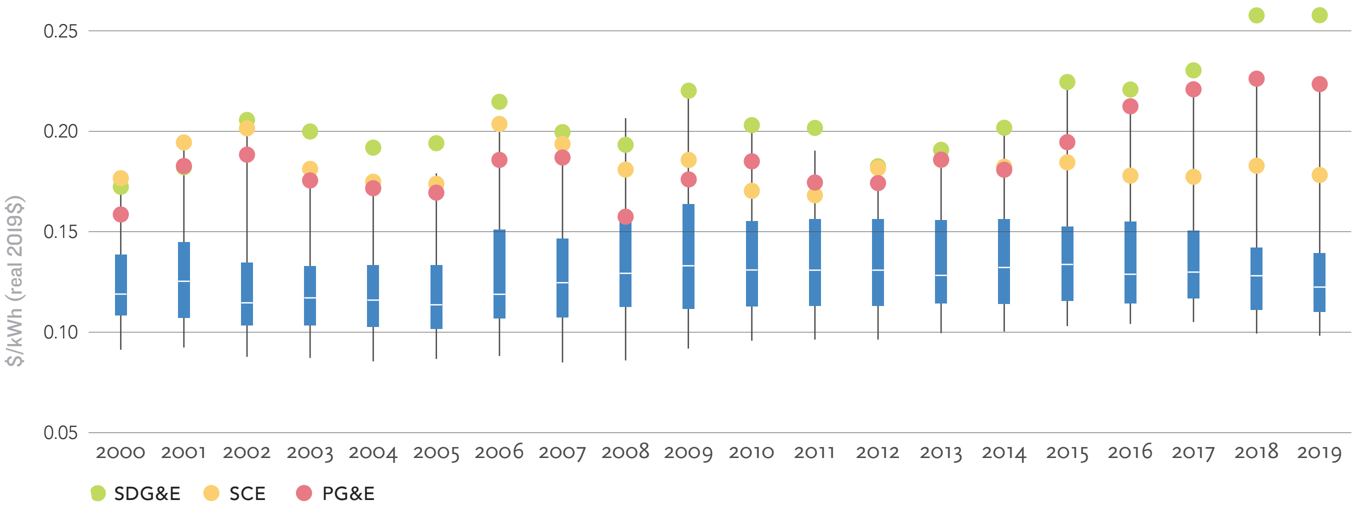


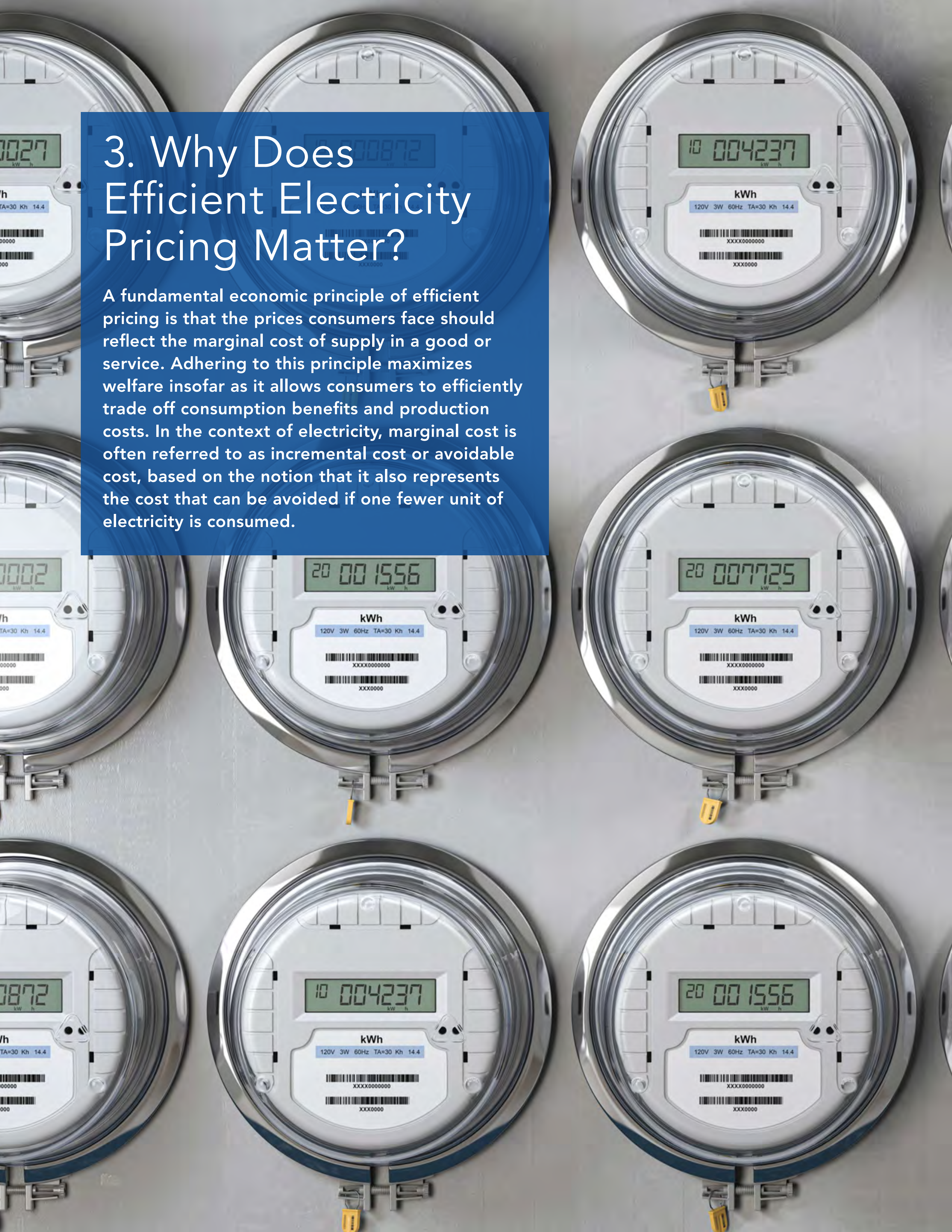
FIG 1 Average Residential Price ($/kWh) by Year for Major U.S. Utilities



Note: Observations are weighted by total annual consumption. The box represents the 25th, 50th, and 75th percentile. The whiskers represent the 5th, and 95th percentiles. Source: Data come from FERC Form 1.

Figure 1 presents the overall average residential rates, including those on low-income rates (CARE). In 2019, over a quarter of California IOU customers were enrolled in the CARE program.[4] When CARE customers are removed, average rates for non-CARE households are about 10 percent higher.

4 IOU annual reports on low income assistance programs indicate the share of residential customers that are presumptively eligible for CARE is in the range of 26-28%. All three utilities report very high (90-96%) CARE participation among eligible households.



3. Why Does Efficient Electricity Pricing Matter?

A fundamental economic principle of efficient pricing is that the prices consumers face should reflect the marginal cost of supply in a good or service. Adhering to this principle maximizes welfare insofar as it allows consumers to efficiently trade off consumption benefits and production costs. In the context of electricity, marginal cost is often referred to as incremental cost or avoidable cost, based on the notion that it also represents the cost that can be avoided if one fewer unit of electricity is consumed.

The concept of marginal cost depends on the time horizon being considered and the question being addressed. For example, at a moment in time when a system has excess power and is curtailing wind generation, the marginal cost of supply is effectively zero, because curtailing a little less wind power and instead delivering it to a customer would be virtually costless. But over the longer run, if wind generation would have to be expanded to meet a higher level of long-run demand, the marginal cost would include the cost of the wind turbine hardware. If additional demand in some hours of a year would require additional generation, transmission or distribution capacity, then the marginal cost of accommodating that additional demand would include the capacity investment cost that could otherwise be avoided or deferred. To the extent that there are many hours over the year in which the additional capacity may be utilized, then it is appropriate to allocate the cost of the additional capacity over those hours.

Societal, or social, marginal cost (SMC) includes not just costs borne by the producer, but also any external costs that are imposed in the production or consumption of the good. In the case of electricity production, the most notable externalities are the environmental impacts of pollution that are not fully reflected in electricity market prices. Explanation of how private marginal operating costs, private marginal capacity costs, and emissions-related external marginal costs were estimated is below and in the Appendix.

If the incremental, or "volumetric," price is set higher than SMC, then it will discourage usage of the good in some cases where it creates more value than it imposes costs. For instance, if a consumer would get $10 of value from consuming an additional unit of a good, and doing so would create an additional $5 in cost to the producer and an additional $2 in pollution externality costs, then this unit of consumption still creates $3 in net additional value ($10-$5-$2). However, if the volumetric price of the good is set, for instance, at $11, then the consumer will choose not to purchase it, because the price is greater than the value that the consumer would get.[5] That failure to purchase the good means that the $3 in value is lost. Such "deadweight loss" from under-consumption is avoided if the price of the good is set equal to its SMC—in this case $7.

Similarly, for the same good, if the price were set at $5, then it would encourage use of the good even in cases where it creates less value than the cost it imposes. In that case, for instance, if there were a customer who valued the good at $5.50, that person would buy the good, but this would lower value in the economy by $1.50, the difference between the customer's value of the good and the SMC of supplying it. Thus, this transaction would create $1.50 in deadweight loss from over-consumption.

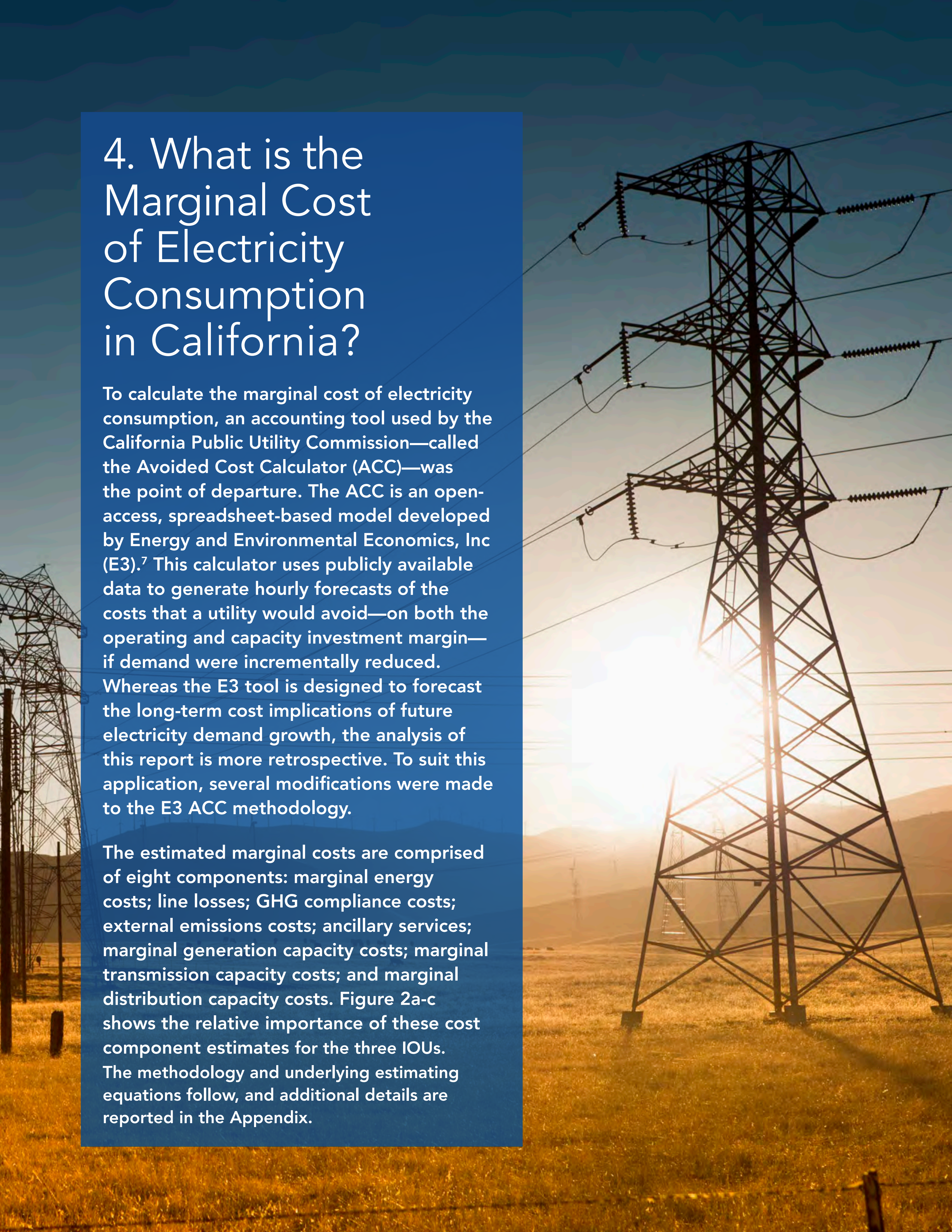
These hypothetical examples have very tangible applications in electricity pricing. Previous research suggests nearly all of California is pricing electricity well above its SMC, as is much of the Northeast, though to a somewhat lesser extent.[6] Many parts of the coal-reliant upper Midwest, however, are pricing well below their SMC, which is quite high due to the pollution from burning coal. In California, over-pricing electricity will inefficiently discourage some households from considering electrification of space heating, water heating, clothes drying, vehicle transportation and other services that can switch between energy sources. In regions that are underpricing electricity compared to SMC, there is too little incentive to adopt energy efficiency improvements that would maximize economic value creation.

One might ask whether this problem of over-pricing compared to SMC isn't ubiquitous in the economy, and why it should be more of a concern in electricity than elsewhere. It is true that many branded consumer goods are priced above their SMC, but that is less commonly the case with generic commodities, such as energy and

5 Note that a rational, well-informed consumer will make consumption decisions based on the incremental price, ignoring any costs to them that do not change with their consumption at that time. So, a fixed monthly charge would not affect their incremental (or "marginal") consumption decision. A demand charge on their peak consumption is non-marginal during most hours of the year, but could greatly increase the customer's expected incremental price if their consumption is nearly at their annual peak. There is some controversy about the extent to which electricity consumers act in a way that is as precisely rational as this discussion suggests. Ito 2014 finds that residential customers faced with increasing-block pricing seem to respond to the average price they face across the increasing- block price schedule rather than the marginal price. But recent work, such as Ito and Shuang 2020, suggests that customers don't make such errors when faced with a fixed charge. Ito and Shuang 2020 available at: https://www.nber.org/papers/w26853

6 Borenstein, S. and Bushnell, J. "Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency." Energy Institute at Hass. July 2019. Available at: https://haas.berkeley.edu/wp-content/uploads/WP294.pdf

agricultural products. Furthermore, with many branded consumer goods—from new cars to airline tickets to groceries—price discrimination (charging different prices across customers even though the cost of supplying is the same) is a deeply ingrained part of the market. That discrimination is generally intended to pull in the customers with a lower value of the good while extracting high prices from those with a higher valuation. This practice exists to some extent in residential electricity pricing with prices that vary depending on the use of the electricity—such as special lower rates for EV charging. With the need for separate wiring, metering and billing, however, such market segmentation is costly and cumbersome. Moreover, it requires regulators to make price-setting decisions based not just on cost, but also on demand factors—a topic on which there is likely to be widely divergent views.

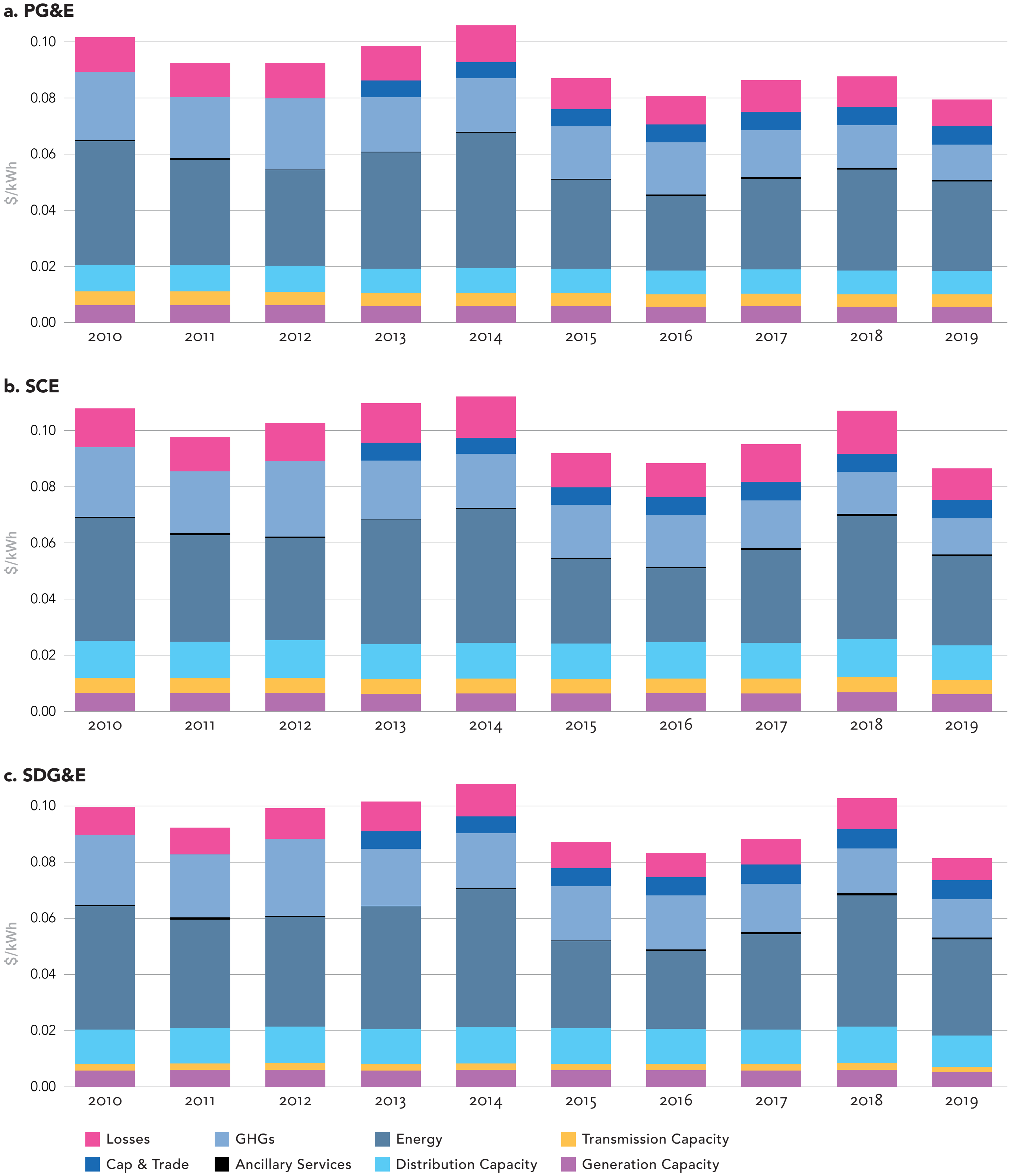


4. What is the Marginal Cost of Electricity Consumption in California?

To calculate the marginal cost of electricity consumption, an accounting tool used by the California Public Utility Commission—called the Avoided Cost Calculator (ACC)—was the point of departure. The ACC is an open-access, spreadsheet-based model developed by Energy and Environmental Economics, Inc (E3).[7] This calculator uses publicly available data to generate hourly forecasts of the costs that a utility would avoid—on both the operating and capacity investment margin—if demand were incrementally reduced. Whereas the E3 tool is designed to forecast the long-term cost implications of future electricity demand growth, the analysis of this report is more retrospective. To suit this application, several modifications were made to the E3 ACC methodology.

The estimated marginal costs are comprised of eight components: marginal energy costs; line losses; GHG compliance costs; external emissions costs; ancillary services; marginal generation capacity costs; marginal transmission capacity costs; and marginal distribution capacity costs. Figure 2a-c shows the relative importance of these cost component estimates for the three IOUs. The methodology and underlying estimating equations follow, and additional details are reported in the Appendix.

FIG 2a-c Annual Social Marginal Cost Estimates ($/kWh)



Notes: Marginal cost components are weighted by IOU load. See text for details on the construction of cost components. Additional details on data sources and methodology behind author calculations can be found in the Appendix.

4.1 Marginal Operating Costs

The first marginal cost component captures variable electricity generation costs by collecting hourly, day-ahead wholesale electricity prices for the default load aggregation points (DLAPS) associated with each of the three IOUs, respectively.[8] These locational marginal prices (LMPs) reflect not only the per-kWh fuel and variable operations and maintenance (O&M) costs at a given location, but also the costs of purchasing GHG permits to offset emissions, congestion related costs, and electricity losses due to long-distance transport.

The first task is to isolate the component of these prices that reflect the marginal cost of electricity generation. Using i to index the IOU territory and t to index hours of the year, the marginal energy cost MEC_{it} is defined as:

(1)

$$MEC_{it} = (LMP_{it} - \underbrace{\tau_t \cdot MOER_{it}}_{\text{GHG Costs}}) \underbrace{\left(\frac{1}{1-LF_{it}}\right)}_{\text{Loss adjustment}}$$

Equation 1 subtracts the GHG compliance costs incurred by the marginal producer from the LMP. To estimate this per-kWh compliance cost, the prevailing GHG permit price, τ_t, is multiplied by the GHG emissions rate (measured in tons of CO2/kWh) of the marginal generator.[9] Assuming that the marginal unit is a natural gas plant, the marginal operating emissions rate ($MOER_{it}$) can be defined as:

(2)

$$\mathrm{MOER}_{it} = \mathrm{HeatRate}_{it} \cdot 0.05307,$$

where $HeatRate_{it}$ measures the fuel efficiency (in MMBtu/kWh) of electricity generation for the marginal producer in region i and hour t. Multiplying by the carbon intensity of natural gas (0.05307 metric tons/MMBtu) yields an estimate of the GHG intensity of electricity production.[10]

To estimate the marginal heat rate in Equation 2, it is further assumed that the LMP accurately reflects the variable operating costs of marginal producers (i.e., fuel costs plus non-fuel costs (NFC) of variable O&M and GHG compliance costs).[11] Invoking this assumption, the marginal heat rate is:

(3)

$$HeatRate_{it} = \frac{(LMP_{it} - NFC)}{(GasPrice_{it} + 0.05307 * \tau_t)}$$

When power is transferred from electricity producers to residential consumers, losses accrue due to physical resistance in the transmission and distribution system. Transmission losses are quite small (typically 1-2%) and are reflected in LMPs.[12] Losses on the lower-voltage distribution systems are substantially greater per kWh and increase with flow on the line.[13] These losses must be accounted for when estimating the marginal cost of serving residential customers. The Borenstein and Bushnell study cited above estimates average annual residential distribution losses at the distribution company level and then derive marginal losses from an engineering relationship. Equation 1 uses these marginal loss factors LF_{it} to scale variable operating costs. This

7 The Commission approved the first ACC in 2005 with Decision (D.) 05-04-24. Subsequent updates and reviews are available at https://www.ethree.com/public proceedings/energy-efficiency-calculator.

8 For each node, CAISO calculates a load distribution factor. These are used to construct load-weighted average prices for each utility. These data were downloaded from SNL Financial. This is a proprietary source of financial data and market intelligence that includes a convenient centralized database of publicly available LMP data.

9 To calibrate the GHG permit prices, we use quarterly GHG permit auction prices. These prices can be found at: https://ww2.arb.ca.gov/sites/default/files/2020-08/results_summary.pdf

10 This emission factor does not include emissions associated with the extraction and delivery of natural gas. These upstream emissions tend to be region-specific and are hard to estimate generically. Further details are available at: https://www.eia.gov/environment/emissions/co2_vol_mass.php

11 To calibrate variable O&M costs, we use the estimates provided in the E3 ACC. These costs are small (on the order of $0.6 per MWh). Natural gas prices are calibrated using IOU-specific volume-weighted average prices. For PG&E, monthly average prices are volume-weighted across northern California hubs. For SCE and SDG&E, prices are volume-weighted across Southern California hubs.

12 To be precise, one should account for transmission losses in deriving the heat rate of the marginal producer from LMPs. We do not make further adjustments, however, because transmission losses are so small and we have no data on variation in the transmission losses of the marginal producer.

13 Borenstein, S. and Bushnell, J. "Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency." Energy Institute at Hass. July 2019. Available at: https://haas.berkeley.edu/wp-content/uploads/WP294.pdf

approximately accounts for the costs associated with distribution system losses.

In sum, Equations 1, 2, and 3 calibrate three cost components: marginal energy costs, GHG compliance costs, and distribution system losses. Figure 2a-c plots load-weighted annual average measures of these marginal cost components. Of these, marginal energy costs are the most economically significant, comprising 30 to 40 percent of social marginal costs. As of 2019, GHG compliance costs comprise seven to nine percent of private marginal costs. Estimated losses increase marginal costs by 10 to 12 percent.

4.2 Ancillary services

Ancillary services (AS) are procured day-ahead, largely on the basis of total load forecast. Reducing load will generally reduce the amount of ancillary services that must be procured to meet system operating protocols. To estimate this marginal cost, the average ancillary service costs reported annually by CAISO were utilized.[14] On a per-kWh basis, these AS costs are small. They are barely visible in Figure 2a-c.

4.3 GHG externality costs

From the inception of the California cap and trade market, in 2013, through 2019, GHG permit prices in quarterly allowance auctions ranged from \$12-\$17/metric ton.[15] These allowance prices fall below standard estimates of the social cost of carbon (SCC).[16] To account for GHG costs that are not captured by GHG permit prices, the authors define a residual GHG cost component:

$$GHG_{it} = (SCC - \tau_t) \cdot MOER_{it} \tag{4}$$

Primary cost estimates assume a SCC of \$50/ton. Under this assumption, current GHG permit prices reflect up to 34 percent of the true social cost of GHG emissions. Figures 2a-c show how accounting for this GHG externality has an economically significant effect on our marginal cost estimates.

4.4 Marginal capacity costs

Thus far, this report has focused exclusively on the variable operating costs (private and social) associated with serving residential electricity demand. Next, the investment margin is considered. In principle, if peak demand for electricity in a utility service territory is reduced, some transmission projects, distribution system upgrades, and/or generation capacity investments could be deferred or avoided. In practice, the ability to defer these investments will depend on a number of factors, such as the location and timing of peak demand reductions.

Annualized cost impacts of incremental reductions in peak load on generation, distribution, and transmission capacity investments are discussed first—followed by an explanation of how these annualized costs are allocated across hours.

4.4.1 Marginal transmission capacity cost (MTCC):

The IOUs coordinate with the California Independent System Operator (CAISO) to plan transmission system investments. If peak load is reduced prior to a project implementation date, a planned transmission project that is driven by anticipated increases in demand—versus regulatory, safety, contractual, efficiency or other reasons—could be deferred.

The E3 ACC tool uses data from general rate cases, and data provided by the IOUs, to identify deferrable transmission investments. These utility-specific marginal capacity costs are measured in terms of dollars per kilowatt-year. The primary estimates of this report incorporate these E3 cost estimates directly. For each IOU, the reported deferrable transmission costs are averaged across the ten-year period considered. Some stakeholders have challenged the idea that any transmis-

14 These AS costs are taken from CAISO's Annual Report on Market Issues and Performance.

15 "California Cap-and-Trade Program: Summary of California-Quebec Joint Auction Settlement Prices." California Air Resources Board. November 2020. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-08/results_summary.pdf

16 Following the 2016 Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis produced by the Interagency Working Group on Social Cost of Greenhouse Gases, we assume that the SCC is \$50/ton. In the Appendix, we also consider a case with SCC equal to \$100/ton.

sion investments are driven by load peak-load growth.[17] In the Appendix, alternative estimates which set MTCC component to zero are reported.

4.4.2 Marginal distribution capacity costs (MGCC):

The costs of operating, maintaining and replacing distribution equipment, once installed, are generally independent of electricity consumption levels. However, there are some types of distribution system investments that can be sensitive to rates of demand growth for a given set of customers. For example, distribution reinforcement investments provide capacity to meet demand growth on the existing system.

The E3 Avoided Cost Calculator leverages information reported in general rate cases to estimate the value of deferring or avoiding investments in distribution infrastructure through reductions in distribution peak capacity needs. These annualized costs, averaged across years, are used to construct this report's primary estimates of IOU-specific marginal distribution capacity costs. However, it should be noted that several stakeholders have challenged the idea that peak load reductions could defer distribution upgrades. Recognizing that these primary estimates may over-estimate distribution investment costs that are truly avoidable, the Appendix also reports marginal cost estimates that set the MDCC component to zero.

4.4.3 Marginal generation capacity costs (MGCC):

When peak demand is forecast to increase, or new generation capacity will be needed to replace retirements, the marginal generation cost captures the cost of procuring and operating new generation capacity (measured in terms of dollars per kilowatt-year). E3 ACC calculations use the levelized capital cost of a new simple cycle combustion turbine generating unit net of profits earned in energy and ancillary service markets to estimate marginal generation capacity costs.

In time periods when peak demand is not forecast to increase, the MGCC captures the going- forward fixed cost of operating existing generation resources net of energy gross margins earned in the energy and ancillary services markets. In GRC proceedings, reported costs capture the fixed O&M, insurance, and property tax costs incurred to keep marginal generation operating. Noting that peak load has been declining over time, the generation capacity costs assumed here are based on resource adequacy cost estimates. The primary marginal cost estimates assume an MGCC of \$30/kW-year.[18]

4.4.4 Hourly allocation of capacity costs:

To construct hourly marginal cost estimates, deferrable capacity costs must be allocated across hours of the year. Intuitively, these costs should be allocated to the hours when demand is likely to be highest. Historical load data is used to summarize systematic variation in hourly IOU load over the period of 2005 to 2019. The objective is to identify the hours in which electricity demand is likely to be highest, and then allocate capacity costs proportionally.

Hourly load is regressed in L $_{h,d,m,y}$ (where h is hour, d is day, m is month, and y is year) regressed on hour-of-day-by-month fixed effects, day-of-week fixed effects, and a set of holiday indicators:

(5)

$$L_{h,d,m,y} = \alpha_{h,d,m} + \lambda_d + \sum \delta_{hol} D_{j,y} + \varepsilon_{h,d,m,y}$$

The regression residual $_{h,d,m,y}$ captures variation in realized load that cannot be captured by our suite of fixed effects.

To predict hourly electricity demand in year y, Equation 5 is estimated using data from the five years prior. Hourly load is then estimated within the year and these hourly load estimates are ranked in descending order. Load in the 501st hour defines a threshold T_y. All hours with predicted load below this threshold receive a weight of zero. Non-zero allocation factors for hours that exceed

17 See for example, the Order Instituting Rulemaking to Create a Consistent Regulatory Framework for the Guidance, Planning and Evaluation of Integrated Distributed Energy Resources. Rulemaking 14-10-003, April 24, 2020.

18 PG&E has calculated a Net Present Value (NPV) sum of the six years of MGCCs and then converted this NPV to a levelized value. PG&E used its after-tax Weighted Average Cost of Capital (WACC) of 7.0 percent. The estimated net costs of capacity: \$30.23/kW-year, \$29.62/kW-yr, \$28.53/kW-yr, \$27.63/kW-yr, \$27.70/kW-yr and \$27.42/kW-yr for 2017 through 2022, respectively.

this threshold are defined as:

Marginal capacity costs (for transmission, distribution, and generation) are allocated across hours of a year on the basis of these weights. Intuitively, for hours in the

(6)

$$w_{ty} = \frac{\hat{L}_{ty} - T_y}{\sum(\hat{L}_{ty} - T_y)}$$

top 500 each year, marginal capacity costs are allocated in proportion to the difference between an hour's load and the threshold load level from the 501st hour. Thus, for instance, the 499th highest load hour would likely get almost no capacity costs allocation, because the load in that hour is probably nearly the same as the load in the 501st hour.

Figure 2a-c illustrates the magnitude of these marginal capacity cost components (expressed in terms of average cost per kWh) relative to other cost drivers. Distribution and transmission costs vary with the size of deferrable investments reported in general rate cases. Across all three utilities, the marginal distribution investment cost component is the largest of the capacity-related cost components.

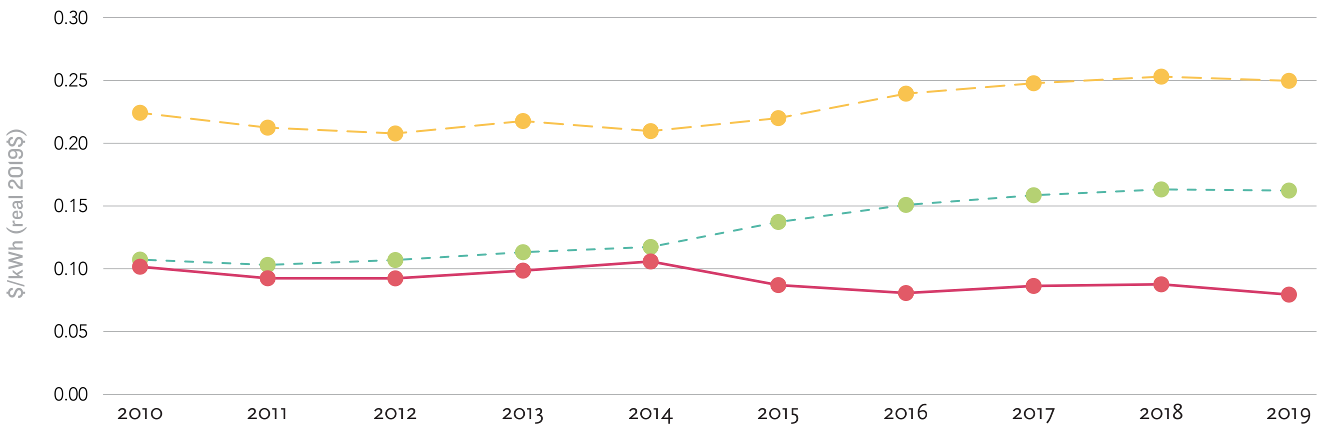
4.5 The widening cost recovery gap

Figure 3a-c illustrates the significant gaps between social marginal cost and average retail prices for customers of all three utilities who are on not on a low-income rate. For PG&E and SDG&E, this gap has grown substantially over time. The SDG&E picture is particularly striking. In 2019, the average non-CARE retail price was more than three times the estimated social marginal cost. Note that the SMC captures not only the private marginal costs incurred by the utility, but also the full social cost of GHG emissions (evaluated at $50/ton CO2). For both SDG&E and PG&E, the gap between subsidized CARE rates and social marginal cost also has been widening over time.[19]

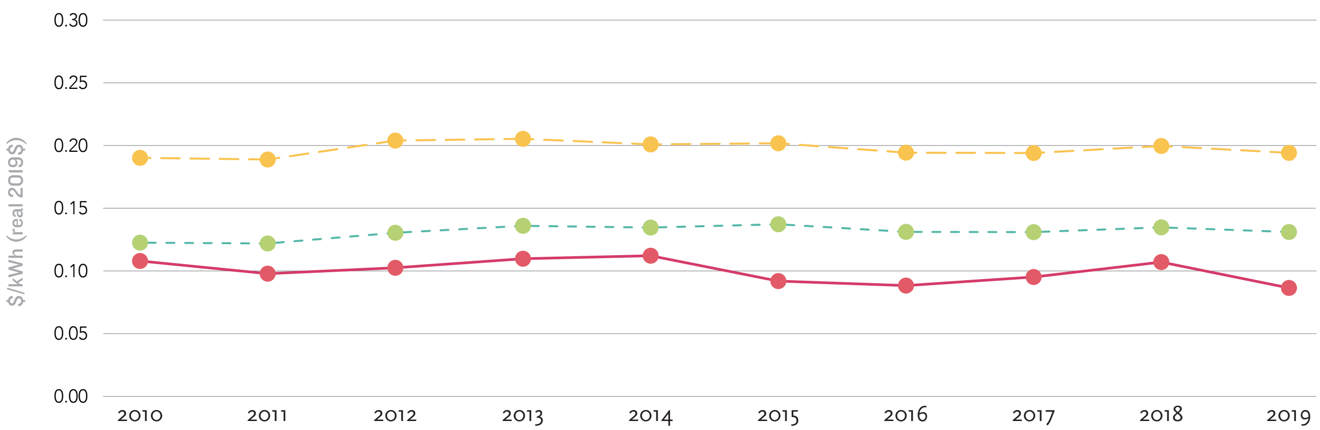
19 The retail price data for Figure 3a-c are created by taking the total residential revenue from FERC Form 1 and solving for the implied CARE and non-CARE prices based on the share of kWh sold to CARE customers and the average CARE discount. The resulting standard rate is 1 to 2 cents lower than the rates shown in Figure 4a-c, which is mostly due to the FERC form 1 data including the California Climate Credit while the bill component figures on which Figure 4a-c are based do not.

FIG 3a-c Retail Price Vs. Social Marginal Cost ($/kWh)

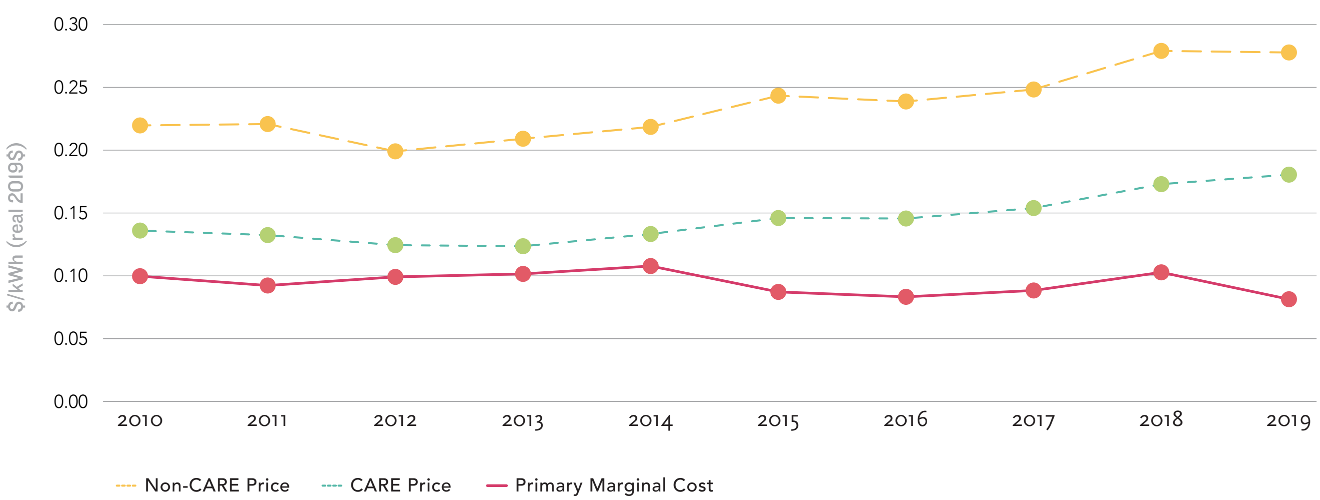
a. PG&E



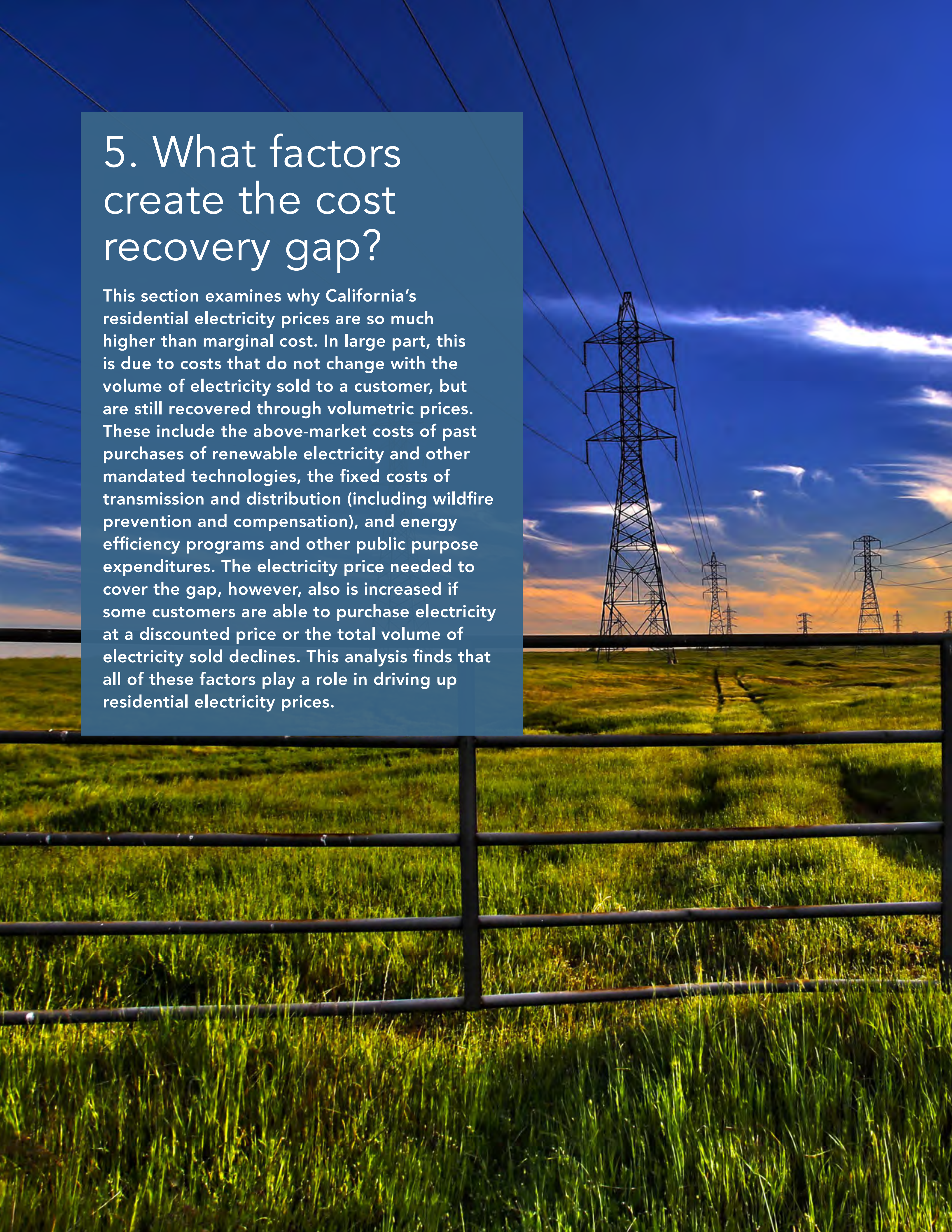
b. SCE



c. SDG&E



Source: Primary marginal cost estimates are authors' calculation explained in text, weighted across hours by IOU load. Average prices for bundled customers are from FERC form 1. CARE and non-CARE prices are derived using CARE and non-CARE kWh, CARE discounts, and participation sourced from CARE cost reports.



5. What factors create the cost recovery gap?

This section examines why California's residential electricity prices are so much higher than marginal cost. In large part, this is due to costs that do not change with the volume of electricity sold to a customer, but are still recovered through volumetric prices. These include the above-market costs of past purchases of renewable electricity and other mandated technologies, the fixed costs of transmission and distribution (including wildfire prevention and compensation), and energy efficiency programs and other public purpose expenditures. The electricity price needed to cover the gap, however, also is increased if some customers are able to purchase electricity at a discounted price or the total volume of electricity sold declines. This analysis finds that all of these factors play a role in driving up residential electricity prices.

Figure 4a-c illustrates both the components of social marginal cost (on the lower "staircase"), and the components of the gap between SMC and the average residential retail price for non-CARE customers (on the upper staircase). The left-most column presents the marginal costs associated with generation in the lower red box and the non-marginal costs associated with generation in the upper red box, and likewise in the other columns for transmission, distribution, greenhouse gas emissions, and a final column for public purpose programs and other expenses, virtually all of which are non-marginal.[20] The box heights in the lower staircase are load-weighted averages over time; both private and externality marginal costs can vary substantially hour to hour. The box heights on the upper staircase, however, are simply a total cost figure divided by quantity. These costs are not associated with supply in any particular hour.[21]

For the generation, transmission, and distribution columns, Figure 4a-c is constructed by starting from the residential bill components under the standard residential rate for each category. The cost is then decomposed between marginal cost (lower staircase) and residual cost recovery (upper staircase) by subtracting off the relevant marginal cost components shown in Figure 2a-c. The residual cost component is then adjusted further due to the existence of CARE and BTM solar, as described in the subsequent paragraphs. The pollution column shows the cap and trade liability for the marginal kWh and the additional externality cost above the emitter's cap and trade liability. Note that the cost of the additional externality is not borne by the producer, so is not part of the private marginal cost explained in this figure. Thus, the bottom of the next column begins at the top of the cap and trade box, not at the top of the non-market GHGs box. The pollution column is the end of the marginal cost components. Total private marginal cost is the top of the cap and trade box and total social marginal cost is the top of the non-market GHGs box. The costs represented in the right-hand column are not marginal in that they do not change with the consumption of the household paying the bill.

5.1 Generation

Figure 4a-c shows generation costs both as part of marginal cost on the lower staircase and as significant residual costs on the upper staircase. The energy costs, as explained above, are based on wholesale electricity prices, adjusted upward to reflect distribution line losses.

California's high electricity prices have occasionally been attributed to its aggressive adoption of renewable generation under the Renewables Portfolio Standard (RPS) program. In 2019, all electricity retail sellers had an annual target to serve at least 29 percent of their electric load with RPS-eligible resources. Under this RPS, utility-scale solar and wind generation capacity had reached almost 12,000 MW and 6,000 MW, respectively, by 2018.[22]

To the extent that qualifying renewable resources are more expensive, the RPS mandate will increase the cost of electricity generation. The CPUC tracks RPS and non-RPS procurement expenditures in terms of $/kWh and annual RPS revenue requirements.[23] RPS procurement costs have fallen at a rate of 13 percent per year between 2007 and 2019. In 2019, the average RPS energy contract price across all technology types was $28/MWh. As renewable energy technology costs have fallen, so has the above-market premium for renewable energy generation. The average difference in RPS versus non-RPS procurement costs reported by the large investor-owned utilities had dropped to $0.0028/kWh in 2019 (CPUC, 2020).

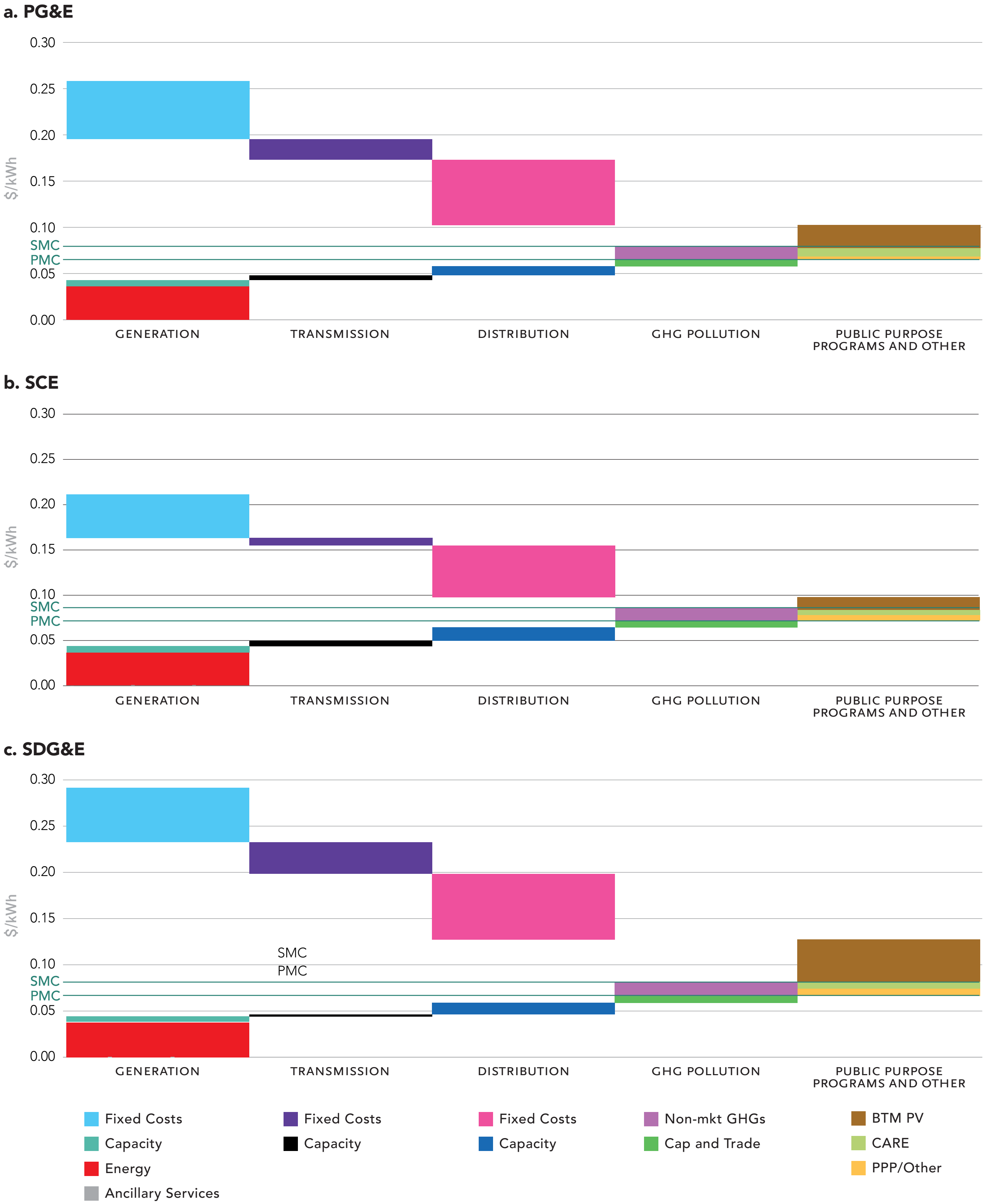
20 Figure 4a-c does not include costs of other pollutants that are associated with supplying electricity. In our continuing research, we are working to include costs of these pollutants. Borenstein and Bushnell, 2019, however, suggest that in California by far the largest negative air pollution externality associated with electricity supply is the emissions of greenhouse gases.

21 The CARE and BTM PV total costs are affected by the particular hours in which CARE customers and customers with BTM PV consume electricity, but are not associated with supply to most standard-rate customers.

22 2018 Total System Electric Generation. California Energy Commission. 2019. Available at: https://www.energy.ca.gov/ data-reports/energy-almanac/california-electricity-data/2019-total-system-electric-generation.

23 The CPUC is required to report annually to the state legislature on the progress of electricity retail sellers in meeting their RPS goals and substantive actions taken to achieve those goals. Two reports that are required annually have information on 1) RPS program costs and 2) progress and status of the RPS program. Past reports to the Legislature are available at: https://www.cpuc.ca.gov/RPS Reports Data.

FIG 4a-c Residential Price Decomposition ($/kWh) for 2019



Notes: Primary marginal cost estimates are weighted by IOU load. Average 2019 residential prices (CARE and non-CARE) are constructed using advice letters and rate schedules PG&E sources: 5366-E-A/B; 5444-E; 5573-E; 5644-E. SCE sources: 67666-E: 67668-E. SDGE: 31811-E; 31501-E. Details on the methodology behind author calculations can be found in the Appendix.

Dividing the utility-specific RPS revenue requirements by the corresponding RPS procurement cost (per kWh) yields an estimate of the quantity of electricity procured to comply with the RPS mandate. This quantity was then multiplied by the reported RPS cost premium to estimate the additional generation costs incurred to meet RPS obligations. Assuming that 40 percent of RPS compliance costs are recovered from residential customers, the impact of the RPS mandate on residential retail prices (in terms of $/kWh) can be estimated.[24] On a per kWh basis, these residential rate impacts of RPS compliance are small. In 2019, SDG&E paid no price premium for RPS-eligible procurement. The authors estimate average residential rate impacts per kWh of $0.006 and $0.0001 for PG&E and SCE, respectively. These cost differences for renewables comprise a very small part of the generation component of the upper staircase in Figure 4a-c. The large "Generation Fixed Costs" boxes for all three utilities represent contracts and utility-owned generation at costs well above 2019 market prices for all types of generation.

5.2 Transmission and distribution

For all three utilities, fixed costs of transmission and distribution (T&D) comprise more than half of the total fixed costs that are recovered in standard rates, before accounting for the cost shifts from CARE and behind-the-meter solar PV. These fixed costs include amortization and return on capital for investments in T&D. They also include all of the operation and maintenance expenditures for transmission and distribution that must be done to keep the lines in-service, including vegetation management. These are not rate-based capital investments, but they are nonetheless fixed costs in that they do not vary with the amount of electricity a household uses.

As mentioned earlier, while some amount of these costs are a result of wildfire risks and past damages, the report authors have not been able to access the data necessary to determine how much. Fixed cost due to wildfires include additional vegetation management, technology that monitors for wildfires near power lines, technology to detect line faults and shut off power before the line starts a fire, patrolling power lines during high fire risk periods, relocation of power lines, early replacement of lines and towers to reduce fire risk, and compensation for fire damage for which the CPUC determines ratepayers will contribute.

5.3 Energy efficiency and other public purpose programs

The lowest box in the right-hand column of Figure 4a-c represents all payments for public purpose programs except CARE. This includes energy efficiency programs, energy research and development programs, and subsidies for customer-sited batteries, among others.

5.4 Behind-the-meter solar PV

California's retail electricity pricing structure, together with the state's net energy metering (NEM) policy, have been important drivers of "behind the meter" solar PV (BTM PV) adoption. By 2018, 6,854 MW of distributed solar had been installed under the NEM program, 4,356 MW of which is residential.[25] This level of investment in distributed solar PV is significantly less than the utility-scale investments mandated under the RPS. However, the authors estimate that the retail rate implications of BTM PV investments have been much larger, as illustrated by Figure 5.

Residential customers with PV systems are credited at the retail electricity rate for every kWh of solar electricity they generate.[26] This effectively shifts the burden of fixed cost recovery onto customers that have not adopted BTM PV. As Figure 4a-c clearly shows, this confers a generous subsidy because residential rates significantly exceed social marginal cost (which includes, among other components, the estimated social cost of greenhouse gas emissions). Importantly, the growing gap between the retail rate and marginal cost reflects costs that are not

24 The CPUC is required to report annually to the state legislature on the progress of electricity retail sellers in meeting their RPS goals and substantive actions taken to achieve those goals. Two reports that are required annually have information on 1) RPS program costs and 2) progress and status of the RPS program. Past reports to the Legislature are available at: https://www.cpuc.ca.gov/RPS Reports Data.

25 California Distributed Generation Statistics. California Solar Initiative (CSI) Available at: https://www.californiadgstats.ca.gov/

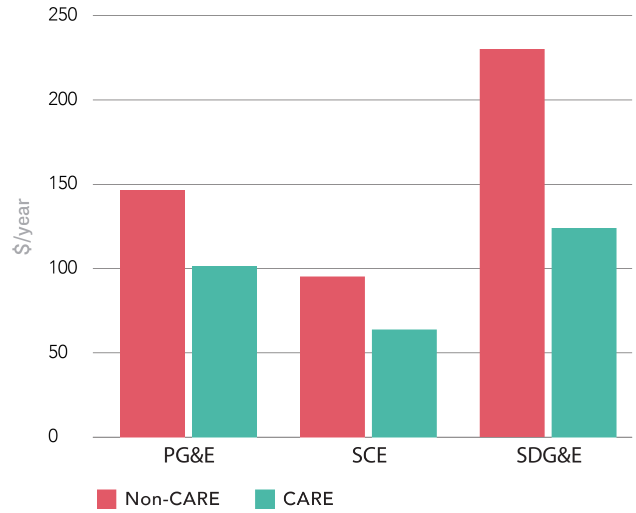
26 Under NEM2.0, which began in 2017, owners of rooftop solar now pay a small amount to cover their share of public purpose programs and a couple of other small charges, totaling about 2.5 cents per kWh.

avoided—only shifted—when a household adopts PV.

To assess the residential rate implications of this cost shift, the authors estimate what residential rates would have been absent investments in residential solar PV.[27] For each utility-year, the electricity generated by installed residential BTM PV was simulated and then this generation was added to the residential electricity sales actually observed. Next, an estimate of how much lower retail rates would have been had costs been spread across this broader base of residential electricity consumption was established. To streamline these calculations, the authors assume that PV systems are adopted by non-CARE customers and that residential electricity demand is perfectly inelastic.[28] The height of the box labeled "BTM PV" shows the implied retail price impact. These calculations serve as approximate estimates of the residential rate increase attributable to BTM PV incentives.[29]

To put these rate impacts in perspective, the implications for annual electricity expenditures were assessed. Absent household-level data, this analysis is limited in the extent that it can characterize the distribution of this cost shift across different types of households. However, it was possible to estimate average bill impacts for CARE and non-CARE households. Annual CARE reports estimate the average annual electricity consumption among non-CARE and CARE households, respectively. Assuming no change in the share of CARE costs borne by the residential sector, the number of CARE customers, and the CARE discount relative to the non-CARE rate, the average bill impacts of BTM PV incentives can be estimated. Figure 5 shows economically significant annual bill increases for both CARE and non-CARE customers. The impacts are particularly striking in SDG&E territory where residential PV generation accounted for more than 20 percent of residential consumption in 2019. Non-CARE and CARE rates increase by five cents and three cents, respectively. This translates into annual average bill increases of approximately $230 and $124 for non-CARE and CARE customers.

FIG 5 Household-Level Bill Impacts of BTM PV Incentives ($/year)



Notes: CARE and non-CARE rate impacts are authors' calculations. These assume that all PV systems are owned by non-CARE customers. Estimated annual average bill increases are based on average annual electricity purchases among CARE and non-CARE households. Further details on data sources and the methodology behind author calculations can be found in the Appendix.

5.5 CARE program for low-income customers

Between 25 and 30 percent of all residential electricity is sold to low-income customers at reduced rates, which by statute are 32.5 to 35 percent lower than the standard rates. The cost of this subsidy is borne by all other customers, both residential and non-residential.

The height of the CARE box in Figure 4a-c is constructed by calculating the difference between the rate that non-CARE customers pay and the rate that they would pay if there were no CARE program. If there were no CARE program, the standard rate would be somewhat lower than the top of the upper staircase because with additional customers on the standard rate, that rate would not need to be as high in order to cover the full revenue requirement from residential custom-

27 This is equivalent to assuming that the utility institutes a feed-in tariff policy in which all output from residential solar is compensated at the utility's marginal (i.e., avoided) cost.

28 Residential electricity demand is not perfectly inelastic. The simplifying assumption of perfectly inelastic demand will result in an under-estimation of the rate impacts of BTM-PV incentives. The assumption that all solar PV is adopted by non-CARE households is also strong. To the extent that solar PV is supplying CARE households, this assumption will over-state the rate impacts of BTM-PV incentives.

29 We assume that installation of behind the meter solar PV has no effect on the consumption of the household, either decreasing it due to greater environmental awareness or commitment to reducing pollution, or increasing it due to "moral licensing" of greater consumption or in response to actual lower opportunity cost of consumption under Net Energy Metering if solar panel output would otherwise exceed household consumption.

ers. That revenue requirement would change, however, because the transfer from non-residential to residential due to CARE—which occurs because the CARE subsidy is financed with an equal surcharge on all other kWh, including non-residential—would be eliminated. The counterfactual standard rate if there were no CARE program was calculated by solving simultaneously for the counterfactual standard rate and the new residential revenue requirement in the absence of CARE. Note that the height of the CARE box is not the full burden of the CARE program on other electricity prices. The majority of the CARE subsidy is covered through higher rates to non-residential customers.

6. Volumetric cost recovery is quite regressive

The current approach to raising revenues creates equity concerns because low-income consumers spend a larger share of income on energy consumption.[30] What other options does California have for raising revenue to achieve cost recovery for the electricity system and to support other worthy priorities? In principle, any source of revenue could be used to cover these, so an expansive view of the problem should consider all major sources of revenue to the state.

California tax revenue comes primarily from income and sales taxes, as summarized in Figure 6. Income tax revenue ($96.8 billion in fiscal year 2018-19) are more than double sales and use taxes ($41.1 billion in 2018-19) in the state. After those, a remaining 18 percent of revenue comes from taxes on corporations, motor vehicle excise taxes, and a collection of smaller sources. Property taxes are an important source of local revenue, but they play a small role at the state level.

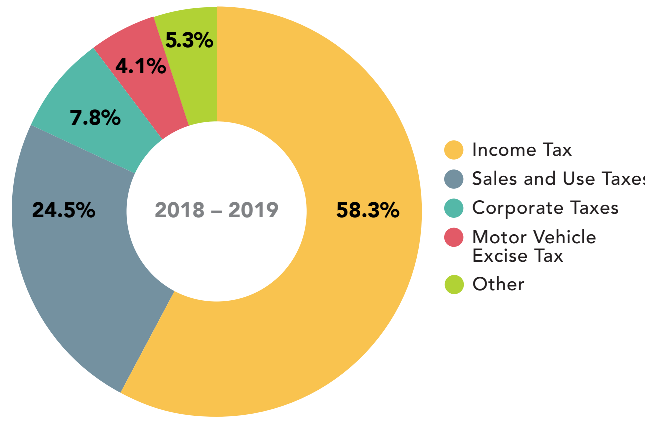
If California shifted some of the cost recovery from electricity rates towards income or sales taxes, what would be the impact on economic efficiency and distributional equity? On equity, a broad strokes answer to this question is provided by the Consumer Expenditure Survey from the US Bureau of Labor Statistics. The survey asks a random sample of U.S. households detailed questions about their expenditures.

Figure 7 plots data on expenditures by income quintile from the 2,469 California survey respondents in the 2017-2018 wave of the survey. Expenditures are normalized to the expenditure of the first quintile (e.g., a value of two implies that the group spends twice as much per household on that category as the lowest income quintile).

These data show that expenditures on electricity do indeed rise with income; the richest households spend almost twice as much as the quintile of households with the lowest income. But total household expenditures rise much more rapidly than electricity, with the richest households spending more than four times the amount of the poorest households on all types of consumption. This means that a tax on all expenditures would be substantially more progressive than a tax on electricity. Gasoline expenditures also rise much faster than electricity.

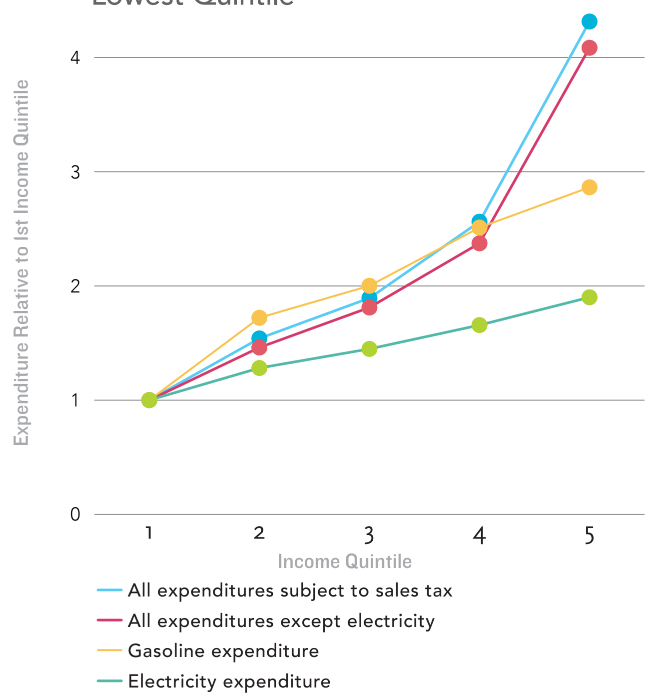
The sales and use taxes in California do not apply to all types of consumption. All of the consumption categories in the survey were coded for this report's analysis according to whether or not expenditures in that category would be predominantly subject to sales and use taxes. Figure 7 shows that relative expenditures of this subset of items tracks the overall level very closely. Thus, collecting

FIG 6 Sources of State Tax Revenue in 2018-19



Source: Authors' calculations of data from the State of California's Comprehensive Annual Financial Report For the Fiscal Year Ended June 30, 2019. Total tax revenue in FY 2018-19 was $168.3 billion.

FIG 7 Average Expenditures per California Household by Income Quintile Relative to Lowest Quintile



Source: Authors' calculations of data from the Consumer Expenditure Survey in 2017-2018. Source data at https://www.bls.gov/cex/2017/research/income-ca.htm

30 Thompson, A.L. "Protecting Low-Income Ratepayers as the Electricity System Evolves." Energy Law Journal, Volume 37, No. 2, p. 265. 2016. Available at: https://www.eba-net.org/felj/energy-law-journal-volume-37-no2-2016/

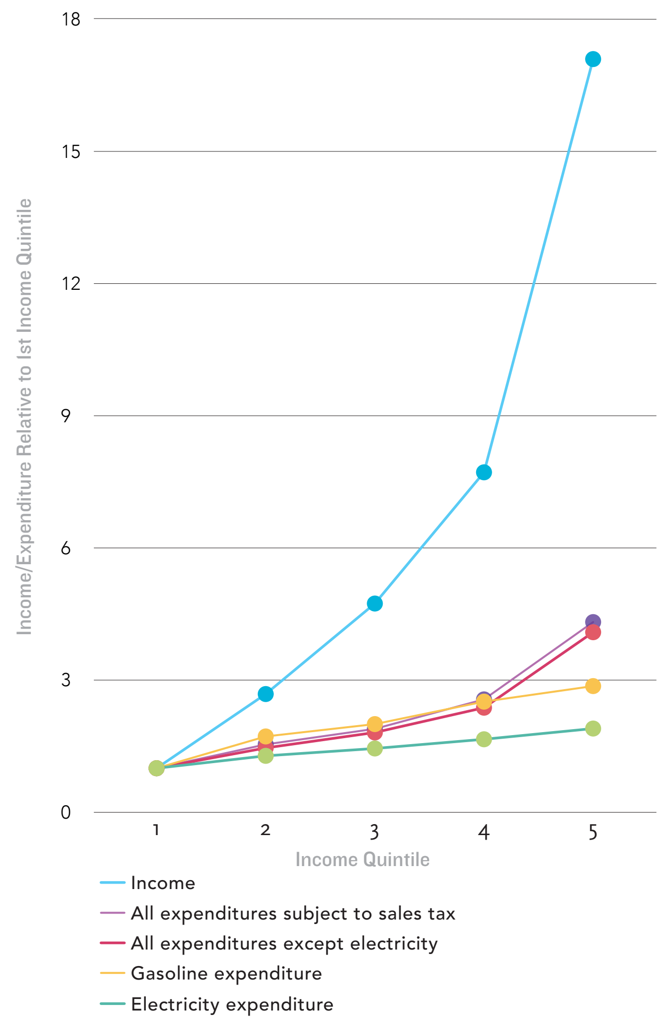
additional revenue from a sales tax also would be substantially more progressive than the current approach.

Collecting additional revenue from the income tax would be even more progressive. To see that, Figure 8 adds mean income within each quintile to the chart. According to the survey, the richest quintile of households have income more than 17 times that of the lowest quintile. As such, even a flat proportional tax on income would be vastly more progressive than the tax on electricity that we currently impose. California's progressive income tax implies an even steeper rise in income taxes paid as a function of income.

In terms of economic efficiency, reducing electricity prices would have the benefits described above in terms of reducing distortions caused by having prices well above marginal cost in the electricity sector. Still, it should be noted that raising revenue through income and sales taxes also creates distortions because these taxes lower the incentive to earn income. Economic theory suggests that the size of these distortions depends on the elasticity (i.e., how responsive is behavior to price) and the size of the pricing distortion squared. Because the pricing distortion for electricity is so large, the inefficiencies from an income or sales tax are likely to be far smaller than the distortions from raising the income or sales tax, but the authors are studying this important question in related ongoing research.

In short, there is good reason to believe that shifting some costs out of electricity rates and onto the general state budget could increase economic efficiency while also improving the overall equity of the system. There are, however, potential headwinds that make such a reform challenging. First is that this transition may face political opposition from those skeptical of adding any liabilities to the state budget. Second is that it does create winners and losers, not only within utility service territories (as will any rate reform), but also between utility territories, including the state's many municipal utilities. About 30 percent of California households are not customers of the three IOUs, and pricing implications differ even across those three. If system costs were funded through statewide revenue sources, it would effect a

FIG 8 Average Expenditures and Income per California Household by Income Quintile Relative to Lowest Quintile



Source: Authors' calculations of data from the Consumer Expenditure Survey in 2017-2018. Source data at https://www.bls.gov/cex/2017/research/income-ca.htm

transfer of resources from municipal customers to the IOUs and among the IOUs towards those with higher system costs.

If the goal is to better align customer prices with social marginal cost while still recovering total costs, the alternative to raising revenue elsewhere is to reform electricity rates, which avoids some of those potential objections. This approach is discussed next.

7. Fixed charges can be made more equitable

Fixed monthly charges have long played a role in residential electricity billing. They are very attractive on efficiency grounds, allowing the utility to cover a revenue gap with almost no risk of customer departure, while keeping volumetric prices close to marginal cost. They also have some appeal on fairness, based on the argument that everyone who uses the system should contribute to the infrastructure that supports it. But, fixed monthly charges that are the same for all residential customers are also highly regressive; they take a much larger share of household income or expenditures from lower-income households than from wealthy customers.

Fixed charges that vary with a household's income can retain much of the efficiency appeal of an undifferentiated fixed charge, while at the same time being more equitable. Still, implementation of such a tariff faces significant practical and administrative hurdles because of the need to verify income. And even if one decided to implement an income-based fixed charge, there are still many choices to be made because there are a multitude of possible ways to structure an income-based fixed charge, in terms of both the rate and the practical implementation. This section discusses the main options and obstacles in broad terms, and then sketches proposed rate structures as examples.

This report does not attempt to address all the relevant details here, which would inevitably be the subject of negotiation between utilities, customers, regulators, and other parties. Instead, the goal is to describe the core idea and identify the main conditions that would make it feasible to simultaneously improve the efficiency and equity of California's electricity rates via income-based fixed charges.

7.1 Core principles: efficiency, cost recovery, equity and feasibility

Roughly following Bonbright's principles, four principles should guide the design of an income-based fixed charge: efficiency, cost recovery, equity and feasibility.[31] In brief, a tariff should be designed that (1) sets volumetric prices as close to social marginal cost as possible, (2) recovers full system costs, (3) is fair in its allocation of burdens, and (4) respects administrative, legal and political limitations. Each of these criteria is discussed briefly next.

7.1.1 What is an efficient rate?

The core objective of this analysis is to propose a tariff that is more economically efficient. Roughly, this means a tariff with volumetric prices that are as close to social marginal cost as possible.

As discussed earlier, in many circumstances, when the price of a good equals its marginal cost (inclusive of externalities) the optimal (efficient) amount of that good will be produced and used, and it will be allocated among users so as to maximize its value. The analogous point for electricity is that its marginal price should be equal to social marginal cost.[32]

The ideal tariff thus charges social marginal cost per kWh, inclusive of generation costs, pollution impacts, and system costs that scale with usage. This applies the marginal, or avoidable, cost concept discussed extensively in Section 3. In addition, the volumetric rate should be time varying, as marginal costs vary across hours and days. The volumetric rate should also vary across space to the extent that transmission congestion implies different costs of delivering power to different locations within a utility's service territory. The additional complexities of time and location varying costs, which have been discussed extensively elsewhere, are not addressed in this analysis.[33]

CARE rates, increasing block pricing and climate zone baselines are instruments designed to alter the distributional outcomes of the current rate structures that charge prices well above avoidable cost. All of these features could be eliminated in a scheme that achieves equitable distribution through income-based fixed charges.[34]

Prices set at social marginal cost would encourage

31 Bonbright, J.C. "Principles of Public Utility Rates." Columbia University Press. 1961. Available at: https://www.degruyter.com/document/doi/10.7312/bonb92418/html. Available at: https://www.journals.uchicago.edu/doi/abs/10.1086/706793

32 Note, however, that it is not in fact ideal to price electricity exactly at its social marginal cost when the alternatives to electricity are themselves mispriced. To the extent that the price of natural gas and petroleum motor fuels differ from their social marginal cost—because, for example, producers and users do not have to pay the full cost of associated emissions (as well as congestion and accident costs for motor fuels) or fixed infrastructure cost recovery drives price for the alternative fuel above SMC—the optimal price for electricity may be somewhat below or above its social marginal cost. For a related analysis pertaining to the usage of electric vehicles, see Davis and Sallee (2020) cited in earlier footnotes. Here we focus simply on social marginal cost as a benchmark.

33 See for instance, Borenstein and Bushnell (2019) and Burger et al. (2020) in earlier footnotes.

34 Increasing-block pricing is also supported by some who believe that higher prices are appropriate in order to encourage conservation. However, by setting price equal to SMC, regulators encourage the efficient amount of conservation, because consumers face a price that reflects the full social cost of their consumption. Furthermore, Ito (2014) finds that increasing-block pricing does not reduce consumption overall compared to a price that does not change with quantity consumed, but yields the same average price across all customers. Climate zones are also partially intended to benefit households in hotter areas, but if income-based fixed charges were implemented, it is not clear why one would want to further benefit households in one area versus another. If redistribution to households in hotter areas were a policy goal, one could have lower fixed charges for households in those areas. Ito (2014) available at: https://www.aeaweb.org/articles?id=10.1257/aer.104.2.537

users to use electricity when their benefit from usage exceeds the cost to society of producing and delivering electricity and to make appropriate investments in energy efficiency and fuel switching. Thus, a rate reform that moves volumetric prices closer to social marginal cost will generate efficiency improvements.[35]

It is important to note that income-based fixed charges themselves could in principle induce inefficient behavior, because households may be deterred from earning more if their electricity bill rises with income. For example, if the fixed charges are a step function of income (what tax economists refer to as a notch in the tax schedule), then there could be an incentive to keep reported income below a critical cutoff. Similarly, if fixed charges are a smooth, rising function of income, they could have the same efficiency implications as an increase in the income tax rate, to the extent they are salient. Such responses would represent inefficient distortions in behavior. These might only be reporting distortions, but nevertheless, one should be attentive to perverse incentives that might be created by the fixed charge schedule because they erode efficiency (and, potentially, fairness).

Finally, there is another potential distortion from having fixed charges if some customers may disconnect from the grid to avoid the charge. Such a response would be potentially quite inefficient, but at this point there seems to be little risk of significant grid defection.[36]

7.1.2 What is a rate that achieves cost recovery?

An economically efficient volumetric price will recover some amount of revenue, but it will be substantially less than the total revenue requirement for California IOUs. The point of fixed charges is to recover the remaining costs without pushing volumetric prices above SMC.

This elides the more nuanced question of which costs ought to be recovered via electricity bills at all. As noted above, an appealing alternative is to simply recover some fixed costs via another revenue source, such as the income or sales tax. The discussion in this section is focused on establishing the relative merits of using different components of electricity bills to recover system costs. But whether some categories—like energy efficiency programs or wildfire mitigation—can nevertheless be moved out of electricity rates entirely should be an ongoing debate.

The possibility that utility costs are excessively high, whether because of mismanagement, poorly designed regulatory incentives, or ill-advised mandates is also not addressed in this analysis. Setting aside the question of whether costs can be reduced, the amount of revenue that must be recovered through charges to electricity customers is taken as given.

7.1.3 What is an equitable rate?

An income-based fixed charge can be made to have a wide range of possible structures that would distribute the burden of paying for the electricity system across households differently. What would make such a system equitable?

The component of the electricity system costs that does not change with level of household usage is effectively a public good among customers. Economists often use three distinct but related equity criteria to determine who should pay for a public good. One is the ability to pay principle: people with greater income or wealth should contribute more. A second is the benefits principle: those who benefit more from the public good should contribute more. A third is the responsibility principle: those who cause the need for the public good should contribute more.

Emphasizing the ability-to-pay principle naturally suggests income-based fixed charges as a means to make cost recovery relatively progressive. There is no universal agreement on how progressive revenue collection should be, but a useful benchmark is to consider what rates would be like if they were as progressive as other sources of state revenue that are used to fund public goods, namely the California income and sales taxes.

Another common understanding of fairness is based upon changes from the current status quo. Some may view a rate reform as unfair if it causes certain people to pay more. It is inevitable that a rate reform will cause some people to pay more and some less than under

35 With price set equal to SMC, optimal levels of energy efficiency might still not result if consumers are poorly informed about the efficiency of devices and the range of alternatives. It seems likely, however, that information provision or standards would be more effective for such specific cases than general increases in electricity prices.

36 Gorman, W., Callaway, D.S., and Jarvis, S. "Should I Stay or Should I Go? The Importance of Electricity Rate Design for Household Defection from the Power Grid." Applied Energy. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0306261920300064

the current system, but it may be deemed important to ensure that certain groups of customers are not made worse off by a reform. To that end, the report explores rate designs firstly where households with the lowest income pay no more than they do today.

A final element is what economists sometimes call horizontal equity—which states that people who are similar in income should pay similar fees. Here, a potential threat to horizontal equity is if a rate structure has large, discrete jumps in fees at particular income cutoffs, then customers who are very similar in income may pay very different amounts.

7.1.4 What is a feasible rate?

Finally, implementation costs must be factored into analysis of alternative rate designs. This has several implications.

First, implementation of a rate may require new information to be collected or shared between institutions. The feasibility criterion requires that information sharing be permissible under the law and broadly acceptable among customers. It also requires that administrative costs of new information collection and processing be recognized and included in the analysis.

Second, it should not be overly burdensome on consumers. Consumers should be able to understand their rates and should have minimal additional burden imposed upon them.

Third, feasibility requires that the system be designed so that it is possible to collect credible income information about households. If the system is easily manipulated, then the principle of equity will be undermined.

The principle of feasibility imposes some real constraints on our proposed design, so we dis- cuss several key related issues in the next section before sketching out some hypothetical rates.

7.2 Administrative pathways towards an income-based fixed charge

In order to assess fixed charges that vary by income, there needs to be some marriage between utility billing data and information about income. There are several ways to achieve this. Four possibilities are outlined here, which range from one extreme that fully integrates utility billing with the state's income tax to another extreme that requires the utilities to conduct all of the income verification themselves. In between are a range of options that attempt to leverage the administrative strengths of state agencies for purposes of income verification, which are discussed third. The fourth approach explored levies fees at the community level rather than at the level of the individual in order to sidestep the challenge of verification.

Before detailing these, conceptual issues around the use of income as a primary measure are briefly discussed.

7.3 Measuring income

Like nearly all utility programs for the needy, this analysis focuses on current income as a measure of financial well-being. Economists have long recognized that this is not an ideal indicator. Lifetime income or wealth are likely to better indicate financial need of an individual or household. Unfortunately, data on such broader measures are even more difficult to access or estimate than measures of current income, so any feasible scheme is sure to rely on the less ideal, but commonly accepted, measure of current income.

A preferred measure of current income upon which to based fixed charges would account for all of the income earned by people who share the same utility account, but adjust charges in some way to account for the number of individuals served by an account, so as to better reflect the financial resources and financial needs of a household.

This presents some significant practical challenges. Because fixed charges would be higher when more sources of income are reported, customers might not have an incentive to accurately report all of the income-earning individuals associated with an account if asked. The system could be based by default on the income of the account holder (and spouse if married filing jointly), but inclusion of any other individuals in the household headcount would also require reporting of their income.

In the calculations below, households are sorted by household income, as reported to the Census Bureau, but no adjustment for household size is made. This gives a useful view of the income distribution, but it should be noted that full implementation might involve some scaling by household size and must grapple with the issue of adding up income when an account serves multiple adult earners.

7.3.1 Model 1: Revenue balancing with the Franchise Tax Board

From an information point of view, the best way to measure income is to use the income tax system. If an income-based fixed charge were fully integrated with California's state income tax, a scheme could proceed as follows.

Each utility would collect a fixed monthly charge from each account holder in each year. The utility would submit an information return to the tax filer and to the Franchise Tax Board stating two things: the total fixed charges paid by each account holder during the calendar year and the number of months that the account was active. The state's income tax form would include a calculation of the amount of utility cost recovery owed based on the account holder's income and the months of service. This would be similar to the documents filed for mortgage payments and myriad other tax provisions.[37]

If an account holder had been charged more than the amount they owed, then they would receive a credit. If they had paid too little already, then they would owe an additional payment. In either case, this payment would be rolled into the filer's state income tax reconciliation. The Franchise Tax Board (FTB) would then balance the account with each utility. This would act the same as any other fully refundable tax credit. If consumers did not wish to report any of this type of information to the utility, they could simply pay some default rate (which would presumably be high) and effectively opt out.

The great advantage of this system is that it assigns the logistical tasks to the institutions with the expertise and infrastructure to handle them best and imposes minimal additional burden on customers.

The Franchise Tax Board has all of the relevant information about income and already processes billions of information returns. The utilities are asked only to tally up one item from within a billing system that they are already operating. Customers need only provide a social security number, and they will need to add just one number on their tax return to claim a credit if they have overpaid. In addition, by operating directly through the tax system, it is easy to allow for fixed charges that are complex functions of income.

A simple approach is to collect the same high monthly fixed charge from all households, and then rebate overpayments as part of the tax return. But this would pose a significant burden on lower-income households. So, it seems important to give lower-income households, or perhaps all households, an option to make lower payments. This is very similar to employer withholding in the income tax system. It would be straightforward to develop a form that is analogous to the W-4 tax form through which account holders would make declarations about their income and household size, which would then be translated into a monthly payment amount. If that amount turns out to be too high or low, the difference would be reconciled on the return.

There are challenges associated with this approach. First, not all account holders file tax returns. Some method of accommodating such households without requiring them to process a full return just to claim their credit would be essential.

Second, there is an issue of underpayment and overpayment. Presumably, the FTB would just be a passthrough entity, not liable to the utility for a customer who doesn't pay and not having a claim on any overpayment from customers, or customer failure to claim a credit they are owed.

Third, there is a question of administrative cost. If the tax agency incurs costs on behalf of the utilities, it would presumably be necessary for the utilities to pay those costs out of their own revenue. So, some procedure for calculating those costs would be required.

Finally, perhaps the most important obstacle is that this approach uses the tax system to collect revenue for a private entity. This is quite rare, and it may raise a host of objections, legal and philosophical. This may be an insurmountable barrier. If so, then this scenario might be understood not as a likely outcome, but as a model against which to compare other schemes that try to leverage information sharing to enable an income-based fixed charge without involving the FTB in actual revenue collection or balancing.

37 It would be convenient for the utilities to file information returns based on the account holder's social security number (or taxpayer identification number), but if that poses privacy concerns, it would be straightforward for the tax agency to establish a personal identification key that maintains privacy.

7.3.2 Model 2: Opt-in verification only

The opposite extreme is for the utilities to be solely responsible for income verification, without the aid of the FTB or other state institutions.

Utilities would need to gather information about income from all account holders in order to sort them into the relevant categories. Account holders would have strong incentives to report lower income than the truth if it qualified them for substantial discounts. Thus, if utilities used the low cost option of simply asking customers to report their income, it seems likely that there would be substantial misreporting that would undermine the viability of the system.[38]

Instead, the utilities could require specific documentation of income. The obvious problem with that is that utilities would need a costly new administrative infrastructure for processing millions of financial documents. Likewise, customers would be burdened with significant hassle costs, as they would need to produce and share various documents with the utility. In addition, most ways of validating income would contain private information like social security numbers.

Utilities do not already have an infrastructure for verifying income, nor do they have any special expertise in such matters. Currently, CARE eligibility is determined by a self-declaration of the account holder. Auditing of these declarations is quite limited, and households face little or no penalty for declarations that they cannot substantiate. Thus, the administrative structures surrounding CARE seem to be a thin foundation for the more expansive system needed to execute an income-based fixed charge for all customers.

A system in which the utilities attempt to charge income-based fixed charges without direct cooperation from other state agencies seems seriously problematic. This leads to the next consideration: alternatives that do not rely on the tax system actually collecting revenue but do leverage information available in state institutions that can be shared with the utility.

7.3.3 Model 3: Information sharing without revenue collection

The prior two options represent extremes along a spectrum. In between are ways that the utilities and its customers could leverage the information available within state agencies in order to facilitate an income-based fixed charge. Here there are also a range of approaches.

Rather than actually collecting revenue, the FTB could simply report to the utilities the income associated with each account. This could be done on a rolling basis based on the prior year's tax return, or even prospectively based on withholding information.

A variant of this approach is to let consumers voluntarily send tax return documentation to the utilities for purposes of verification. But this involves greater hassle costs for customers, requires the sharing of personal information with the utilities, and requires the utilities to interpret and handle large volumes of documents.

Any version of information sharing that requires the utilities to handle, process and interpret a large flow of incoming documentation for its entire customer base is an inefficient use of institutional expertise. A more cost effective approach is to have the FTB produce a database that associates a fixed-charge rate with each account.[39]

The Franchise Tax Board does not have full income information for all account holders because not all people file an income tax return, and, if the analysis is based on a prior year's tax return, not all people will have paid taxes in the state in the prior year. Moreover, income changes over time, so it would be desirable to allow changes in income to impact rates more quickly than implied by a full year's delay based on the tax return cycle.

This suggests an enhanced version where the database provided to the utilities has information augmented by information returns held by the FTB and/or participation in other programs that screen households for eligibility based on income. That is, the database could identify house- holds as eligible for lower rates proactively based on participation in CalFresh, housing voucher programs, enrollment in unemployment or disability insurance, or other such programs. This could greatly improve the

38 CARE eligibility in the current regime is potentially subject to these same problems. It is not clear how many ineligible customers currently are on a CARE rate, but we conjecture that the incentives to misreport would be far more substantial if there was a salient change in the monthly charge associated with specific income thresholds, rather than the current rate discount.

39 Here it becomes useful if there are only a few distinct fixed charges. Then, revealing the rate class that is associated with each account divulges relatively less personal information.

accuracy of the scheme in real time, but it does clearly require a level of coordination across state agencies that may be costly.

Information sharing may also face legal barriers. This report's authors are not legal experts, but it seems likely that legal issues could be avoided if households had to opt-in to information sharing. They could be placed into the highest fixed charge tier unless they authorize the state to release information about which rate class they belong in. (The state does not need to release the information upon which that is based; it only needs to indicate the fixed-charge group.)

If revenue collection and balancing by the FTB is ruled out, the approach that likely yields the most efficient results by leveraging the relative expertise of different institutions is to have the utilities establish criteria for a specific set of rates, then have state agencies compile a database that assigns households to each rate based on tax information, supplemented by program participation to help incorporate non-filers, which the utilities use to assign a default rate. Customers who believe that this process puts them into the wrong group could appeal. Such an appeal might require some level of documentation. Presumably, these appeals would be adjudicated by the utilities or an independent consultant.

Note that many of the variants of this approach use the idea of defaulting customers into a higher fixed charge. If this option is considered a remedy for privacy concerns or hassle costs, then it is important to cap the fixed charges at a reasonable level, so that many customers actually belong in the highest rate class and if customers are wrongly put into that class, it need not be financially ruinous. This suggests the possibility that there might be several distinct default rates that vary by location.

7.3.4 Model 4: Presumptive charges by location

A fourth and final approach is quite different: the utilities could assign fixed charges based on the income of the relevant geographic community, such as a census block, block group or tract, based on survey or administrative data.

Households would be assigned a fixed-charge based on the income of the community they live in. This is meant as an imperfect proxy measure of the household's income (and possibly more reflective of lifetime income). Households who in fact have lower income that would qualify them for a lower fixed charge could have the option to present proof of eligibility that would drop them to a lower fee.

This version need involve state agencies only to the extent that they are used as a method of income verification by those who voluntarily choose to do so. But even that is not required; income can be measured with publicly available data from the Census Bureau.

The advantage of this approach is twofold. First, it greatly alleviates the need for household income verification. With relatively precise targeting and broader income classes for each fixed charge tier, it could well be the case that relatively few people would have an incentive to conduct verification. Second, it minimizes potential distortions to income earning. For households that stick with their default charge, there would be no consequence for earning more and thus no distortionary incentive. This would thus be a relatively efficient option, both in terms of economic incentives and administrative cost.

There are, however, two potential drawbacks. One is that such a scheme would be less equitable, as higher-income households that happen to live in lower-income neighborhoods would be getting lower charges than those with the same income who lived in a neighborhood with higher average incomes. If income verification is challenging, some who are eligible for a lower rate may not take it up.[40]

A second complication is that economic theory suggests that the person who benefits from a favorable rate might be the current landowner, rather than a renter or future buyer. The reason is that a fixed charge would essentially become an attribute of a home or apartment. If a landlord can offer an apartment that comes with a low monthly utility fee, they may be able to charge a higher rent. This would potentially mean that the benefits intended to go to lower income households in fact could flow to the people who sell them housing. Note that, where voluntary income verification is straightforward, this might be a benefit that the landlord could only extract value from if the renter has above average income for the neighborhood.

40 Census data that detail the income distribution within precise geographic areas could be used to study how much misclassification there would be for a given scheme. Much would depend on how much fixed charges vary (are there many different fixed charges, or only a few?) and how precise a geographic area could be used.

More broadly, the use of differentiated default rates can be integrated with some of the options described above. If a version with strong information sharing from the FTB, spatially differentiated default rates could be applied only to non-filers or those with missing information. Alternatively, spatially-differentiated default rates could serve as a base, but high-income earners identified by the FTB would be assigned a higher rate, whereas those with lower than (local) average income would have the option to provide documentation of eligibility for a lower rate.

7.4 Some example rate structures

This section describes a few possible rate structures that would feature income-based fixed charges. It is worth emphasizing again that there are many ways to construct a rate structure with income-based fixed charges in terms of the number of different rates, the incomes to which they apply, and the progressivity of the schedule. Here, a few simple possibilities are considered in order to illustrate the potential and to offer broad guidance on how high fixed charges might be.

In all of the scenarios, the authors propose that volumetric price be set at avoidable cost that is time- and location-specific. This will raise revenue that leaves a significant cost recovery gap.[41] To estimate the number of accounts at each level of income, data from the American Community Survey (ACS) that details counts of household income at the census block group level for sixteen distinct income categories was used. Block groups were assigned to each utility based on utility boundaries, providing a distribution of household incomes for each utility in 2019.[42]

The estimates in Section 5 suggest that in 2019, the cost recovery gap is $4.3 billion for PG&E, $3.0 billion for SCE, and $1.1 billion for SDG&E. Next, income-based fixed charge schedules that would recover those amounts of revenue are considered. According to FERC data, there are 4.8 million residential PG&E accounts, 4.3 million in SCE, and 1.3 million in SDG&E. This means that, on average, PG&E needs to recover almost $900 per household per year; SCE needs to recover around $700 per household per year; and SDG&E needs to recover around $850 per year. It is important to keep in mind that these are costs that the utilities already do recover. Currently they recover these costs via high volumetric prices. In the alternative discussed here, the total revenue collected is held constant, but these large sums are switched into fixed charges. It is of course possible to recover only some fraction of system costs via fixed charges, in which case volumetric prices would get closer to social marginal cost than they are currently, and fixed charges would be proportionally smaller.

For reference, the uniform fixed charge that would be required to fully eliminate the cost recovery gap if all account holders were charged the same monthly fee is first calculated. Assuming all accounts are active for 12 months, the monthly fixed charge would be $74.02 for PG&E customers, $58.80 for SCE customers, and $70.07 for SDG&E customers. In Figure 9, this is represented by the red horizontal line.

Note that in all of these calculations, it is assumed that a change in the rate structure does not impact the size of the cost recovery gap. This is consistent with the assumption that volumetric prices are exactly equal to social marginal cost in the reformed rate and pollution is fully priced. If so, then any change in consumption as a result of lower volumetric rates leads to a $1 increase in revenue for every $1 increase in total cost.[43]

Two income-based fixed charge schedules are considered here, one pegged to the progressivity of sales tax collections and the other to the income distribution in California, as determined by the data from the Consumer Expenditure Survey we analyzed in Section 6. Those data report sales taxes paid and income earned by household income quintile in California.

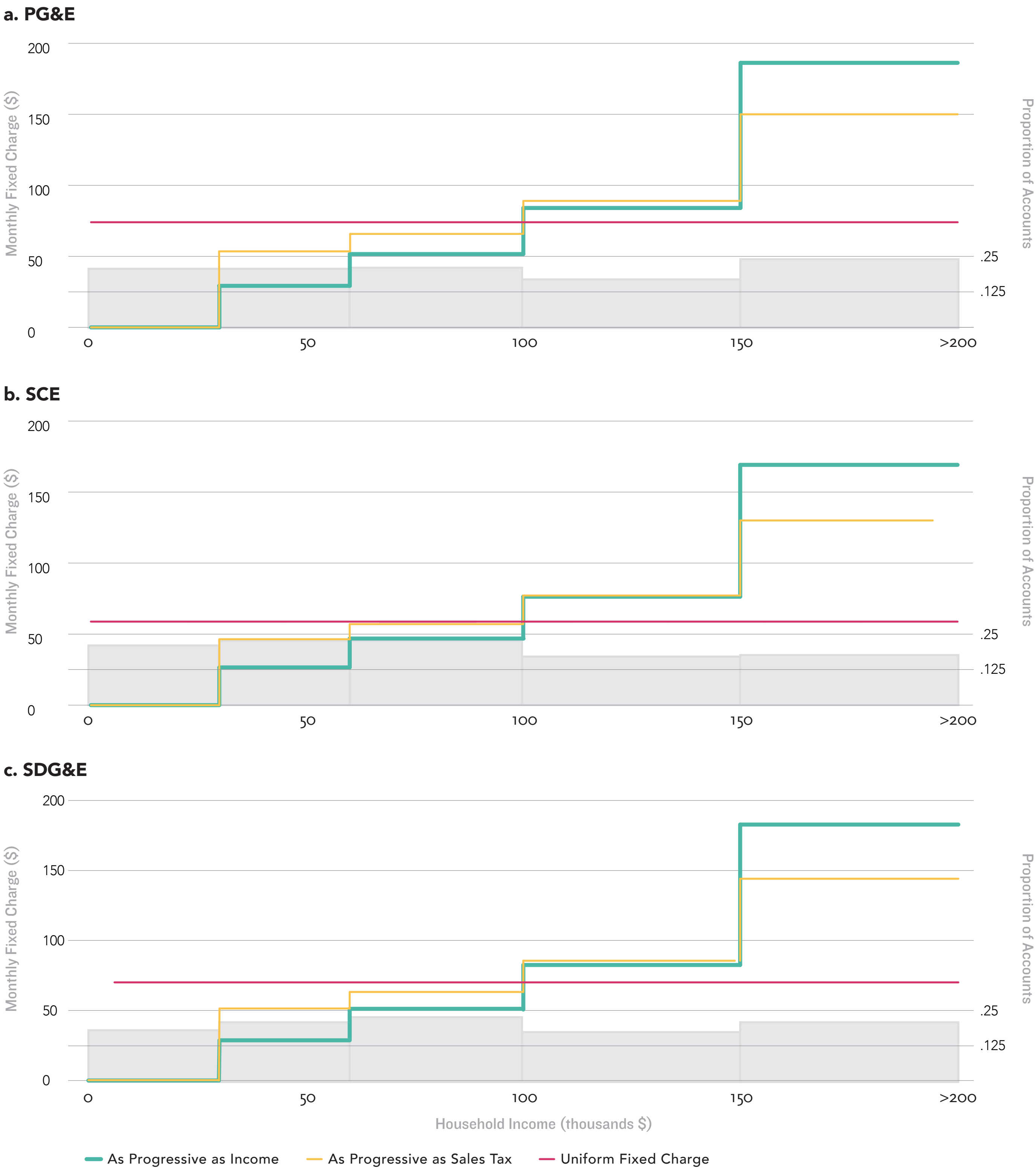
To develop example rate structures, the consumers were divided roughly into quintiles based on household

41 This discussion of alternatives to covering the cost recovery gap implicitly assumes no change in quantity demanded in response to alternative rate designs. However, this would have no impact on the analysis if price were set equal to private marginal cost. Setting price equal to social marginal cost instead implies that increases in quantity would have a small positive impact on utility revenues net of their private marginal cost, which would help to reduce the cost recovery gap.

42 The number of households assigned to each utility from the ACS differs slightly from the number of accounts reported in data from the FERC. We used a deflation factor to adjust the number of ACS households so that it matches the number of accounts reported in each utility service territory.

43 When pollution is priced below its social cost, as it is currently, this gap implies that utilities would recover a small amount of net revenue from an increase in consumption.

FIG 9a-c Example Income-Based Fixed Charge Schedules for 2019



Note: Each scheme depicted recovers the same amount of revenue. The gray histogram shows the proportion of accounts in each of the five pricing tiers in each service territory. Household distribution by income from the American Community Survey. Rates are authors' calculations based on cost recovery gap estimated in this study using proportional fees across quintiles as discussed in text. Full calculations available in the Appendix.

income. (They are not divided perfectly into quintiles because the ACS data reports only sixteen income categories.) It is then assumed that the lowest income quintile is assessed zero fixed charge.

Next, the authors ask what income-based fixed charge schedule would be consistent with a distribution of burdens across the richest four quintiles that is equal to the burden of raising the revenue through the sales tax. In practice, this means that, compared to a household in the second quintile, a household in the third (middle) quintile would pay 23 percent more, a household in the fourth quintile would pay 66 percent more, and a household in the fifth (richest) quintile would pay 180 percent (i.e., not quite three times) more. The state raises a substantial fraction of its revenue through a sales tax that has this same implied burden on its citizens. It is of course possible to dial up or dial down this progressivity, but pegging the progressivity of fixed charges to established sources of revenue provides a useful reference point.[44]

By construction, this schedule would raise revenue in a way that is roughly as progressive as the California sales tax. The implied rate structure for each utility is shown in the yellow lines in Figure 9. For PG&E, the monthly fixed charges would range from $54 for the second quintile up to $150 for the richest quintile (and zero for the lowest income quintile). In SCE, the implied schedule is slightly lower, with a range from $46 to $130 per month. For SDG&E customers, where even more revenue is needed per household, the proposed monthly fees range from $51 to $144.

An alternative is to peg the progressivity of the fixed-charge schedule to the progressivity of the income distribution. The survey data used as a reference point here reports taxable income, rather than state income tax paid. Thus, the tax progressivity is pegged to the income distribution (rather than the burden of the income tax), which is conceptually equivalent to pegging it to the progressivity of a flat income tax. This schedule is substantially more progressive. Again, it is assumed that the lowest-income quintile pays zero fixed charges. Relative to households in the second quintile, households in the third (middle) quintile will pay 77 percent more, households in the fourth quintile will pay 188 percent more (i.e., nearly three times as much), and the fifth (richest) quintile will nearly six-and-one-half times more.

Visually, this results in much steeper schedules, shown in blue in Figure 9. For PG&E, the second quintile would pay only $29 per month (as compared to $54 under the sales-tax motivated scheme), whereas the richest households would pay $186 (as compared to $150).

Again, the monthly charges are slightly lower for SCE customers, with fees ranging between $27 to $169. Monthly rates range between $27 and $169 for customers of SDG&E.

By design, this pricing schedule raises the same amount of revenue from consumers to cover fixed system costs. Overall, consumers would benefit because they would pay the same system costs but would face lower rates, which they could respond to by consuming more. However, any rate reform will create winners and losers. Compared to the current scheme of high volumetric prices, a pricing schedule with these income-based fixed charges would redistribute the burden of cost recovery both across income groups and within income groups depending on household consumption.

Among households in the same income category, those who consume more electricity will benefit more from the introduction of fixed charges. With the anonymized residential billing data requested from the three utilities, it is possible to fully characterize the number of winners and losers and the amount that they stand to gain or lose in each alternative rate reform.

It is thus easy to see how income-based fixed charges, even with a modest tilt to charges, can be much more progressive than the current scheme, in addition to being more efficient. A more comprehensive comparison of the implied change in cost recovery across higher and lower income households will be possible with the billing data we have requested.

There are many additional options that could make the schedule more progressive generally, or more generous to specific groups. For example, the lowest income households could have positive or negative fixed charges. Or, a larger or smaller fraction of households on the lower part of the income distribution could have zero fixed charges. In addition, the schedule need not involve large jumps at specific income thresholds. Fewer distinct categories may simplify the system, but a progressive schedule with few tiers will necessarily involve large price jumps, which can both create perverse incentives and may raise fairness concerns.

44 Note that we design rates for each utility separately, which means that the schedule depends in part on the distribution of income within the service territory. PG&E, for example, has a higher proportion of households in the highest income group.

8. Conclusion: Rate reform can improve both efficiency and equity

High and rising retail electricity prices in California are fueling concerns about equity, affordability and the viability of the state's climate objectives. These high electricity prices are due not to high marginal costs of electricity supply, but rather to the reliance on high volumetric rates to recover system costs associated with transmission and distribution infrastructure, renewable energy subsidies, wildfire risk mitigation, and other factors. This way of recovering costs, which amounts to a tax on electricity consumption, is not only inefficient, it is also inequitable. Because annual electricity expenditure has only a modest correlation with income in California, taxing electricity consumption is quite regressive.

California's plans to electrify transportation and buildings as part of its path to decarbonization will require more investments in the electricity system. As long as the current rate structure remains in place, these investments threaten to exacerbate the inefficiencies and inequities described throughout the report.

This report has proposed some alternative approaches to cost recovery that could out-perform the status quo on both efficiency and equity grounds. These include an income-based fixed charge that could raise revenues in a more equitable way while maintaining an efficient volumetric price. Electricity rate reform will surely present challenges, both practical and political. But rate restructuring is essential to ensure that the California energy transition is both affordable and equitable. It is the authors' hope that this report can help build momentum towards a broader discussion about the best way to pay for electricity in the state.

Just the **FACTS**

Poverty in California

This year's California Poverty Measure estimates describe poverty in 2018—using the most up-to-date data available—and so do not cover the economic impact of COVID-19.

- **Despite improvements, the official poverty rate remains high.** According to official federal poverty statistics, 12.8% of Californians lacked enough resources—about $25,500 per year for a family of four—to meet basic needs in 2018. This represents a modest decline from 13.3% in 2017 and is slightly above the lowest recent rate of 12.4% (in 2007). Moreover, the official poverty measure does not account for California's housing costs or other critical family expenses and resources.

- **Poverty in California is even higher when key family needs and resources are factored in.** The California Poverty Measure (CPM), a joint research effort by PPIC and the Stanford Center on Poverty and Inequality, takes a comprehensive approach to poverty across the state. It accounts for the cost of living and a range of family needs and resources, including safety net benefits. According to the CPM, 17.6% of Californians (about 6.8 million) lacked enough resources—$34,200 per year for a family of four, on average—to meet basic needs in 2018. This is nearly identical to the rate in 2017. Poverty was higher among children (18.8%) and adults age 65 and older (19.0%), and lower among adults age 18–64 (16.8%).

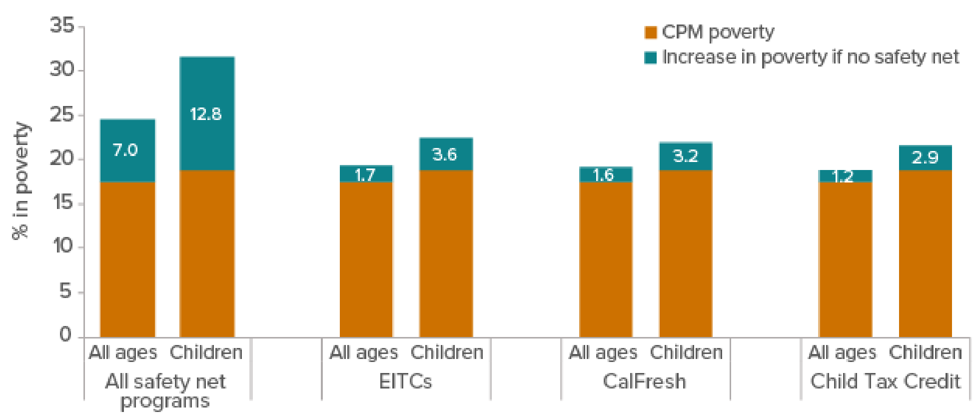
More than a third of Californians are living in or near poverty.

Nearly one in five (17.6%) Californians were not in poverty but lived fairly close to the poverty line (up to one and a half times above it). All told, more than a third (35.2%) of state residents were poor or near poor in 2018. But the share of Californians in families with less than half the resources needed to meet basic needs was 5.1%, a deep poverty rate that is about the same as official poverty statistics indicate.

Without social safety net programs, more Californians would live in poverty.

The largest social safety net programs kept an estimated 7.0% of Californians out of poverty in 2018. Most safety net programs are designed to prioritize children, and in 2018 kept 12.8% of children out of poverty. The combined federal and state Earned Income Tax Credits (EITCs) lowered poverty rates most, by 1.7 points overall, and CalFresh lowered the overall poverty rate by 1.6 points; the federal Child Tax Credit (CTC) lowered the rate by 1.2 points. CalWORKs lowered the rate by 0.8 points. These differing effects reflect program scale and scope as well as participation rates among eligible families.

Poverty would be even higher without the safety net, especially among children



SOURCE: Estimates from the 2018 CPM.

NOTES: “Increase in poverty if no safety net” segments show the estimated increment to the poverty rate if safety net resources are not counted. Program effects may overlap and are not simply additive. Children are ages 0–17. “All safety net programs” includes CalFresh (California’s main food assistance program), Earned Income Tax Credits (federal and state), CalWORKs (cash assistance for families with children), the Child Tax Credit (CTC), Supplemental Security Income (SSI/SSP), General Assistance (GA), federal housing subsidies, the Supplemental Nutrition Program for Women, Infants, and Children (WIC), and school meals.

Poverty rates and the effect of safety net programs vary widely across the state.

Los Angeles (22.3%) and Santa Barbara (21.1%) Counties had the highest poverty rates (2016–2018 average). El Dorado County had the lowest rate, at 10.5%. As shown by PPIC's interactive maps, rates vary even more widely (4.5% to 40.5%) across local areas and legislative districts. Safety net programs reduce poverty much more in inland areas: without them, poverty would be 12.6 points higher in the Central Valley and Sierra, but only 3.4 points higher in the Bay Area. In part, these differences reflect variations in eligibility driven by the cost of living.

Poverty rates vary widely across California's counties

County	Poverty rate (%)	County	Poverty rate (%)	County	Poverty rate (%)
Alameda	14.5	Madera	18.3	San Luis Obispo	14.9
Alpine, Amador, Calaveras, Inyo, Mariposa, Mono, Tuolumne	14.1	Marin	15.5	San Mateo	16.0
Butte	18.3	Merced	15.6	Santa Barbara	21.1
Colusa, Glenn, Tehama, Trinity	15.9	Monterey, San Benito	17.4	Santa Clara	15.5
Contra Costa	13.9	Napa	13.8	Santa Cruz	18.6
Del Norte, Lassen, Modoc, Plumas, Siskiyou	14.0	Nevada, Sierra	18.1	Shasta	18.0
El Dorado	10.5	Orange	19.7	Solano	12.8
Fresno	17.7	Placer	12.1	Sonoma	15.1
Humboldt	19.5	Riverside	17.1	Stanislaus	14.5
Imperial	18.9	Sacramento	16.1	Sutter, Yuba	13.1
Kern	17.6	San Bernardino	16.3	Tulare	18.3
Kings	13.9	San Diego	19.0	Ventura	17.0
Lake, Mendocino	17.3	San Francisco	17.5	Yolo	20.6
Los Angeles	22.3	San Joaquin	15.2		

SOURCE: Estimates from the 2016–2018 CPM combined.

NOTES: For some counties, poverty rates cannot be calculated individually. Those counties are grouped. All estimates are subject to uncertainty due to sampling variability. The uncertainty is greater for less populous counties and county groups (because of smaller survey sample sizes). The statewide margin of error is ±0.3 percentage points. The median county margin of error is ±2.0 percentage points. Margins of error calculated for a 99% confidence interval. For more county-level information and poverty rates by local area and state assembly, state senate, and federal congressional district, see our interactive maps.

Poverty remains dramatically higher among Latinos and less-educated adults.

In 2018, 22.9% of Latinos lived in poverty, compared to 18.2% of African Americans, 15.9% of Asian Americans/Pacific Islanders, and 12.8% of whites, as PPIC's interactive shows. Though the Latino poverty rate has fallen from 30.9% in 2011, Latinos remain disproportionately poor—comprising 51.4% of poor Californians but only 39.6% of the state population. Education continues to be tied to poverty rates: poverty was 7.7% among college graduates age 25–64 and 30.6% among adults age 25–64 without a high school diploma.

Most poor families in California are working.
In 2018, 79.0% of poor Californians lived in families with at least one working adult, excluding families made up of adults age 65 and older. For 44.7% of those in poverty, at least one family member reported working full time for the entire year, while 33.9% had a family member who worked part time and/or part of the year.

Sources: All estimates are based on the California Poverty Measure (CPM) unless otherwise noted. Official poverty statistics in 2018 are from the ACS 1-year estimates available at data.census.gov. For more about the CPM, see Bohn et al., *The California Poverty Measure* (PPIC, 2013). For methodological changes that affect comparability with publications prior to 2016, see Bohn et al., *The California Poverty Measure: 2014* (Stanford Center on Poverty and Inequality, 2017).

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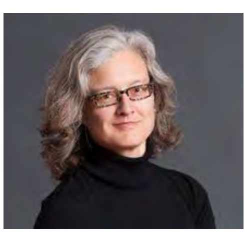
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SEPTEMBER 2020

How High Are Household Energy Burdens?

An Assessment of National and Metropolitan Energy Burden across the United States

Ariel Drehobl, Lauren Ross, and Roxana Ayala

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Contents

Executive Summary

KEY TAKEAWAYS

- New research based on data from 2017 finds that high energy burdens remain a persistent national challenge. Of all U.S. households, 25% (30.6 million) face a high energy burden (i.e., pay more than 6% of income on energy bills) and 13% (15.9 million) of U.S. households face a severe energy burden (i.e., pay more than 10% of income on energy).[1]
- Nationally, 67% (25.8 million) of low-income households (≤ 200% of the federal poverty level [FPL]) face a high energy burden and 60% (15.4 million) of low-income households with a high energy burden face a severe energy burden.
- The East South Central Region (i.e., Alabama, Kentucky, Mississippi, and Tennessee) has the highest percentage of households with high energy burdens (38%) as compared to other regions.
- Black, Hispanic, Native American, and older adult households, as well as families residing in low-income multifamily housing, manufactured housing, and older buildings experience disproportionally high energy burdens nationally, regionally, and in metro areas.
- Weatherization can reduce low-income household energy burdens by about 25%, making it an effective strategy to reduce high energy burdens for households with high energy use while also benefiting the environment.
- Leading cities and states have begun to incorporate energy burden goals into strategies and plans and to create local policies and programs to achieve more equitable energy outcomes in their communities. They are pursuing these goals through increased investment in energy efficiency, weatherization, and renewable energy.

[1] Researchers estimate that housing costs should be no more than 30% of household income, and household energy costs should be no more than 20% of housing costs. This means that affordable household energy costs should be no more than 6% of total household income. For decades, researchers have used the thresholds of 6% as a high burden and 10% as a severe burden (APPRISE 2005). Note that high and severe energy burdens are not mutually exclusive. All severe energy burdens (> 10%) also fall into the high burden category (> 6%).

This report provides an updated snapshot of U.S. energy burdens (i.e., the percentage of household income spent on home energy bills) nationally, regionally, and in 25 select metro areas in the United States.[1,2] Both high and severe energy burdens are caused by physical, economic, social, and behavioral factors, and they impact physical and mental health, education, nutrition, job performance, and community development. Energy efficiency and weatherization can help address energy insecurity (i.e., the inability to adequately meet basic household heating, cooling, and energy needs over time) by improving building energy efficiency, reducing energy bills, and improving indoor air quality and comfort (Hernández 2016).

We recognize that the economic recession brought on by the global COVID-19 pandemic has greatly increased U.S. energy insecurity and also interrupted weatherization and energy efficiency programs nationally. While this report measures energy burdens using 2017 data from the American Housing Survey (AHS), we anticipate the recession will lead to a further increase in energy insecurity and higher energy burdens in 2020 and beyond.

Methods

This study calculates energy burdens using the AHS, which includes a national and regional dataset as well as a dataset of 25 metropolitan statistical areas.[4] We calculate energy burdens across all households and in a variety of subgroups to identify those that spend disproportionally more of their income on energy bills than otherwise similar groups, analyzing across income, housing type, tenure status, race, ethnicity, and age of occupant and structure. We also calculate the percentage of households nationally, regionally, and in each select metro area that have high energy burdens (i.e., spend more than 6% of income on home energy bills) and severe energy burdens (i.e., spend more than 10% of income on home energy bills). We do not include households who do not directly pay for their energy bills.

Energy Burden Findings

NATIONAL ENERGY BURDENS

U.S. households spend an average of 3.1% of income on home energy bills. Figure ES1 presents our national energy burden findings by subgroup. We acknowledge that many highly burdened groups are intersectional, meaning that they face compounding, intersecting causes of inequality and injustice, with energy burden representing one facet of inequity. The following are key national findings:

- Low-income households spend three times more of their income on energy costs compared to the median spending of non-low-income households (8.1% versus 2.3%).
- Low-income multifamily households spend 2.3 times more of their income on energy costs compared to the median spending of multifamily households (5.6% versus 2.4%).
- The median energy burden for Black households is 43% higher than for non-Hispanic white households (4.2% versus 2.9%), and the median energy burden for Hispanic households is 20% higher than that for non-Hispanic white households (3.5% versus 2.9%).
- The median renter energy burden is 13% higher than that of the median owner (3.4% versus 3.0%).
- More than 25% (30.6 million) of U.S. households experience a high energy burden, and about 50% (15.9 million) of households with a high energy burden face a severe energy burden.[5]
- Of low-income households (≤ 200% FPL), 67% (25.8 million) experience a high energy burden, and 60% (15.4 million) of those households with a high energy burden face a severe energy burden.
- Low-income households, Black, Hispanic, Native American, renters, and older adult households all have disproportionately higher energy burdens than the national median household.

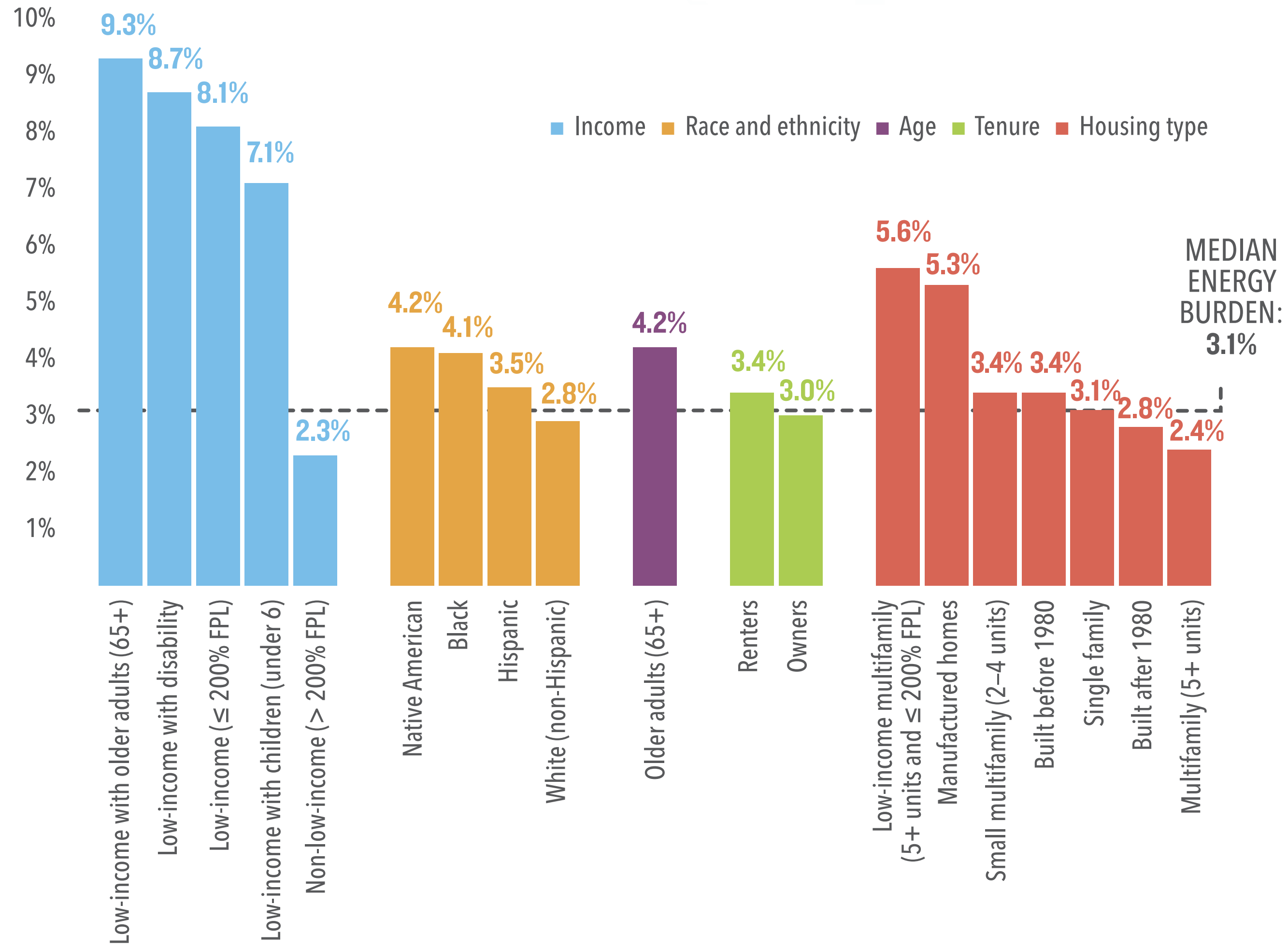
[2] This study focuses on home energy burden and includes electricity and heating fuels. Note that the study does not include transportation, water, or telecommunication cost burdens in its energy burden calculations.

[3] This report provides an update to ACEEE's previous energy burden research. Drehobl and Ross (2016) analyzed 2011 and 2013 American Housing Survey (AHS) data, and Ross, Drehobl, and Stickles (2018) analyzed 2015 AHS data. This report analyzes 2017 AHS data, the most recent data available as of publication.

[4] We include the 25 metropolitan statistical areas (MSAs) sampled for the 2017 AHS: Atlanta, Baltimore, Birmingham, Boston, Chicago, Dallas, Detroit, Houston, Las Vegas, Los Angeles, Miami, Minneapolis, New York City, Oklahoma City, Philadelphia, Phoenix, Richmond, Riverside, Rochester, San Antonio, San Francisco, San Jose, Seattle, Tampa, and Washington, DC.

[5] Note that high and severe energy burdens are not mutually exclusive. All severe energy burdens (> 10%) also fall into the high burden category (> 6%).

FIGURE ES1. National energy burdens across subgroups (i.e., income, race and ethnicity, age, tenure, and housing type) compared to the national median energy burden



REGIONAL ENERGY BURDENS

We find that the national trends hold true across the nine census regions. The following are our key regional findings:

- Across all nine regions, low-income household energy burdens are 2.1–3 times higher than the median energy burden.
- The East South Central region (i.e., *Alabama, Kentucky, Mississippi, Tennessee*) has the greatest percentage of households (38%) with high energy burdens, followed by East North Central (i.e., *Illinois, Indiana, Michigan, Ohio, Wisconsin*), New England (*Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont*), and Middle Atlantic regions (i.e., *New Jersey, New York, Pennsylvania*) (all 29%).
- The gap between low-income and median energy burdens is largest in the New England, Pacific (i.e., *Alaska, California, Hawaii, Oregon, Washington*), and Middle Atlantic regions.
- The South Atlantic region (i.e., *Delaware, DC, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia*) had the greatest number of households (6.3 million) with high burdens, followed by the East North Central (5.4 million) and Middle Atlantic (4.6 million) regions.

METRO AREA ENERGY BURDENS

National and regional patterns are mirrored in cities. The following are our key metropolitan area findings:

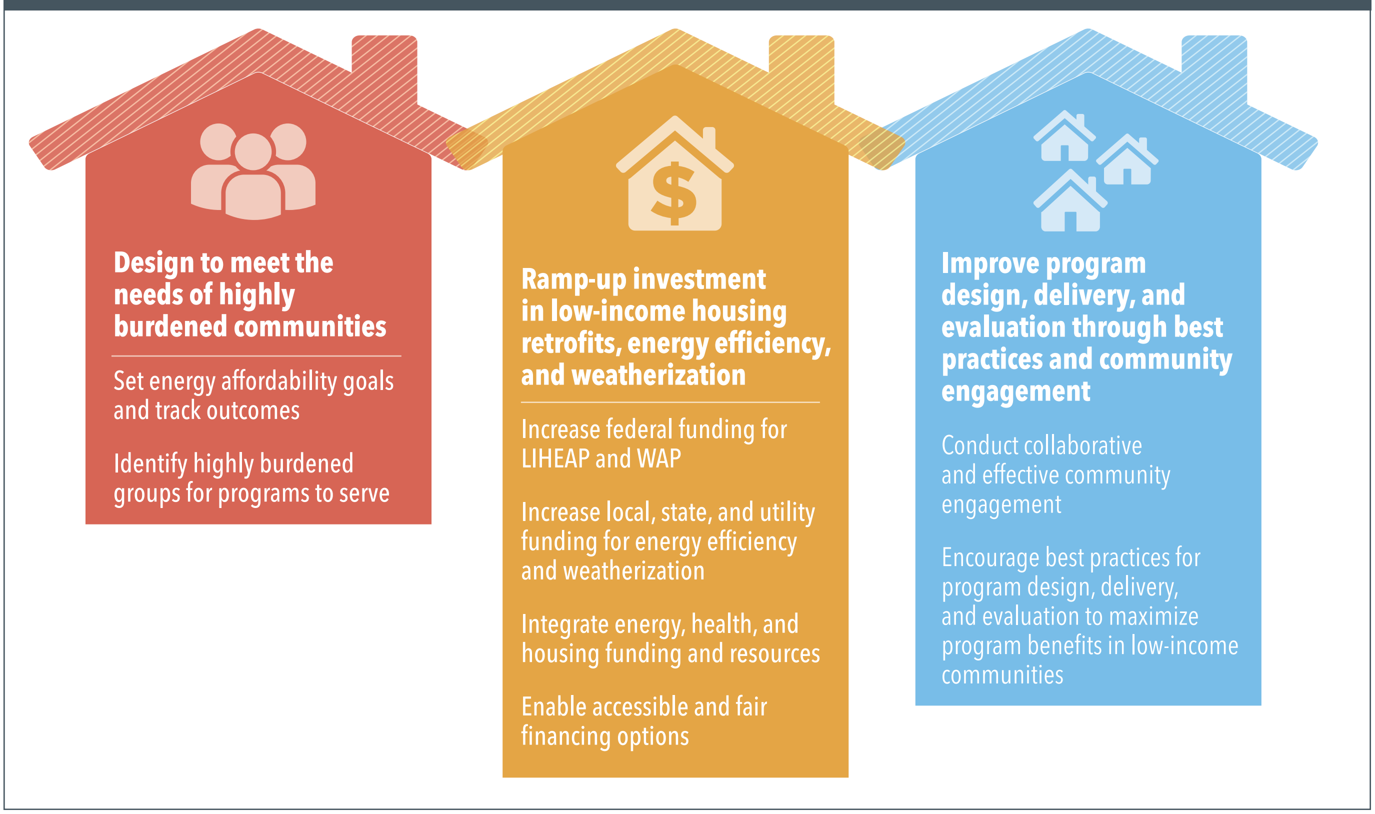
- Low-income households experience energy burdens at least two times higher than that of the average household in each metropolitan area included in the study.[6]
- Black and Hispanic households experience higher energy burdens than non-Hispanic white households; renters experience higher energy burdens than owners; and people living in buildings built before 1980 experience higher energy burdens than people living in buildings built after 1980 across all metro areas in the study.
- Six metro areas have a greater percentage of households with a high energy burden than the national average (25%), including Birmingham (34%), Detroit (30%), Riverside (29%), Rochester (29%), Atlanta (28%), and Philadelphia (26%).
- In five metro areas—Baltimore, Philadelphia, Detroit, Boston, and Birmingham—at least one-quarter of low-income households have energy burdens above 18%, which is three times the high energy burden threshold of 6%.

See the body of the report for additional images, maps, charts, and data on energy burden calculations nationally, regionally, and in metro areas.

Strategies to Accelerate, Improve, and Better Target Low-Income Housing Retrofits and Weatherization

Clean energy investments—such as energy efficiency, weatherization, and renewable energy—can provide a long-term, high-impact solution to lowering high energy burdens. By investing in energy efficiency and weatherization first or alongside renewable energy technologies, these measures can reduce whole-home energy use to maximize the costs and benefits of

FIGURE ES2. Strategies to improve and expand low-income energy efficiency and weatherization programs



[6] We define the "average household" energy burden as the median across all households in the sample (i.e., in each MSA).

Based on prior evidence of how weatherization reduces average customer bills, we estimate that it can reduce low-income household energy burden by 25%.

additional renewable energy generation. This report focuses on weatherization and energy efficiency as long-term solutions to reducing high energy burdens; these solutions can be combined with renewable energy investments and/or electrification strategies that reduce energy bills for additional impact. Based on prior evidence of how weatherization reduces average customer bills, we estimate that it can reduce low-income household energy burden by 25%.[7]

To ensure that more low-income and highly energy burdened households receive much-needed energy efficiency and weatherization investments, we recommend that policymakers and program implementers design policies and programs to meet the needs of highly burdened communities and set up processes for evaluation and accountability processes. This involves engaging with community members from the start, increasing funding for low-income weatherization and energy efficiency, and integrating best practices into program design and implementation. Figure ES2 depicts this actionable framework. For more information about these strategies, see the full report.

Conclusions and Next Steps

Energy affordability remains a national crisis, with low-income households, communities of color, renters, and older adults experiencing disproportionally higher energy burdens than the average household nationally, regionally, and in metro areas. This study finds that each MSA has both similar and unique energy affordability inequities. Further research can help better understand the intersectional drivers of high energy burdens and the policies best suited to improve local energy affordability. Climate change and the global pandemic also underscore the urgency in addressing high household energy burdens. As temperatures continue to rise and heat waves become more common, access to clean, affordable energy is needed more than ever to prevent indoor heat-related illnesses and deaths.

Cities, states, and utilities are well positioned to build on this research and conduct more targeted and detailed energy burden analyses, such as the Pennsylvania Public Utility Commission's study on home energy affordability for low-income customers. Studying energy burden and more broadly analyzing energy insecurity factors are first steps toward setting more targeted energy burden reduction goals and creating policies and programs that lead to more vibrant and prosperous communities.

[7] We assume 25% savings from energy efficiency upgrades based on the U.S. Department of Energy's estimate (DOE 2014) and use the median low-income household values to calculate a 25% reduction. We reduced the median low-income energy bill by 25% from $1,464 to $1,098. Using the median low-income household income of $18,000, this equates to a reduced energy burden of 6.1%. Reducing the median low-income energy burden from 8.1% to 6.1% is a 25% reduction.

Introduction

Energy insecurity—that is, the inability to adequately meet basic household heating, cooling, and energy needs over time (Hernández 2016)—is increasingly viewed as a major equity issue by policymakers, energy utilities, and clean energy and environmental justice advocates. This multidimensional problem reflects the confluence of three factors: inefficient housing and appliances, lack of access to economic resources, and coping strategies that may lead some residents to dangerously under-heat or under-cool their homes (Hernández, Aratani, and Jiang 2014).

Household energy burden—the percentage of annual household income spent on annual energy bills—is one key element contributing to a household's energy insecurity. Energy burden as a metric helps us visualize energy affordability (i.e., the ability to afford one's energy bills); identify which groups shoulder disproportionally higher burdens than others; and recognize which groups most need targeted energy-affordability- and energy-justice-related policies and investments to reduce high energy burdens. Three strategies can reduce both energy insecurity and high energy burdens: increasing household income, increasing bill payment assistance through government or utility resources, and reducing household energy use. This study discusses policy considerations that focus on the third solution of reducing excess energy use to lower high household energy burdens.

This report provides a snapshot of energy burdens nationally and in 25 of the largest U.S. metro areas. We examine median household energy burdens among groups—varying by income, housing type and age, and tenure status—as well as the percentage of households experiencing high (> 6%) and severe (> 10%) energy burdens nationally, in metro areas, and across groups (APPRISE 2005). Building on ACEEE's 2016 urban energy burden study and 2018 rural energy burden study (Drehobl and Ross 2016; Ross, Drehobl, and Stickles 2018), this report analyzes national-, regional-, and metro-level data from the U.S. Census Bureau's most recent American Housing Survey (AHS) conducted in 2017.

Local policymakers, utilities, and advocates can use this report's data and policy recommendations to better understand both which groups tend to have disproportionally higher energy burdens and how they can measure these burdens in their communities. The subsequent policy recommendations focus on low-income energy efficiency and weatherization as high-impact strategies to alleviate high energy burdens and improve overall energy affordability.

Background

Systemic Patterns and Causes of Inequities

Household access to energy is central to maintaining health and well-being, yet one in three U.S. households reported difficulty paying their energy bills in 2015 (EIA 2018). Black, Indigenous, and People of Color (BIPOC) communities often experience the highest energy burdens when compared to more affluent or white households (Kontokosta, Reina, and Bonczak 2019; Drehobl and Ross 2016; Hernández et al. 2016).[8] These communities often experience racial segregation, high unemployment, high poverty rates, poor housing conditions, high rates of certain health conditions, lower educational opportunity, and barriers to accessing financing and investment (Jargowsky 2015; Cashin 2005). Many of these characteristics are due in part to systemic racial discrimination, which has led to long-standing patterns of disenfranchisement from income and wealth-building opportunities for BIPOC communities as compared to white communities (Rothstein 2017).

[8] We use the term BIPOC in this report to describe communities that experience especially acute systemic inequities, barriers, and limited access to energy programs. By specifically naming Black and Indigenous (Native American) communities, the term BIPOC recognizes that Black and Indigenous people have historically experienced targeted policies of systemic economic exclusion, classism, and racism in the United States. It is important to recognize this history and how it has led to disproportionally high energy burdens and unique barriers to accessing clean energy technologies and investments.

Policies and practices that have led to economic and/or social exclusion in BIPOC communities include neighborhood segregation and redlining, lack of access to mortgages and other loans, mass incarceration, employment discrimination, and the legacy of segregated and underfunded schools (Jargowsky 2015; McCarty, Perl, and Jones 2019).[9] These types of systemic exclusions, underinvestments, discriminative lending practices, and limited housing choices have also limited BIPOC communities' access to efficient and healthy housing (Lewis, Hernández, and Geronimus 2019). In addition, Black communities are 68% more likely to live within 30 miles of a coal-fired power plant, and properties in close proximity to toxic facilities average 15% lower property values than those in other areas (National Research Council 2010). Black children are three times as likely to be admitted to the hospital for asthma attacks than white children (Patterson et al. 2014). According to a study by the American Association of Blacks in Energy, while Black households spent $41 billion on energy in 2009, they held only 1.1% of energy jobs and gained only 0.01% of the revenue from energy-sector profits (Patterson et al. 2014).

Systemic exclusions, under-investments, discriminative lending practices, and limited housing choices have limited Black, Indigenous, and People of Color communities' access to efficient and healthy housing.

Limited Access to Energy Programs

A growing body of research shows that BIPOC and low-income communities experience disparate access to residential energy-saving appliances and other energy efficiency upgrades. While low-income and communities of color on average consume less energy than wealthier households, they are more likely to live in less-efficient housing (Bednar, Reames, and Keoleian 2017). Researchers found that, when holding income constant, BIPOC households experience higher energy burdens than non-Hispanic white households (Kontokosta, Reina, and Bonczak 2019). BIPOC and low-income communities also may experience higher costs when investing in energy-efficient upgrades. For example, a study based in Detroit found that energy-efficient lightbulbs were less available in high-poverty areas and smaller stores, and when they were available, they were more expensive than in other areas (Reames, Reiner, and Stacey 2018).

Others have found that untargeted utility-administered energy efficiency programs do not effectively reach BIPOC and low-income communities—particularly those living in multifamily buildings (Frank and Nowak 2016; Samarripas and York 2019). Low-income communities face economic, social, health and safety, and information barriers that impact their ability to access programs, and many programs fail to address these barriers through specific targeting practices. Limited access to energy efficiency resources and investments coupled with lower incomes increase the proportion of income that low-income and BIPOC households spend on energy bills (Jessel, Sawyer, and Hernández 2019; Berry, Hronis, and Woodward 2018).

Where utilities do administer programs targeted at low-income customers, participant needs far exceed available resources. Reames, Stacy, and Zimmerman (2019) found that 11 large investor-owned utilities across six states have distributional disparities in low-income investments; that is, they do not spend energy efficiency dollars proportionally on programs designed to reach low-income populations. A 2018 report found that only 6% of all U.S. energy efficiency spending in 2015 was dedicated to low-income programs (EDF APPRISE 2018). Most states require that utility energy efficiency program portfolios be cost effective, often using tests that focus mostly on direct economic costs to the utility (Woolf et al. 2017; Hayes, Kubes, and Gerbode 2020). This requirement places an additional burden on utilities, states, and local governments that invest in programs that serve low-income communities because it does not account for nonenergy and additional health, economic, and community benefits in program planning and evaluations.

Definition and Drivers of High Energy Burdens

High energy burdens are often defined as greater than 6% of income, while *severe energy burdens* are those greater than 10% of income (APPRISE 2005).[10] Past research found that low-income, Black, and Hispanic communities, as well as older adults, renters, and those residing in low-income multifamily buildings experienced disproportionally higher energy burdens than other households (Drehobl and Ross 2016; Ross, Drehobl, and Stickles 2018).

[9] *Redlining* is the discriminatory practice of fencing off areas in which banks would avoid investments based on community demographics. Redlining was included in local, state, and federal housing policies for much of the 20th century. For more information on historical forms of economic and social exclusion, see *The Color of Law: A Forgotten History of How Our Government Segregated America* by Richard Rothstein.

[10] Researchers estimate that housing costs should be no more than 30% of household income, and household energy costs should be no more than 20% of housing costs. This means that affordable household energy costs should be no more than 6% of total household income.

TABLE 1. Key drivers of high household energy burdens	
Drivers	**Examples of factors that affect energy burden**
Physical	Housing age (i.e., older homes are often less energy efficient)
	Housing type (e.g., manufactured homes, single family, and multifamily)
	Heating and cooling system (e.g., system type, fuel type, and fuel cost)
	Building envelope (e.g., poor insulation, leaky roofs, inefficient and/or poorly maintained poorly maintained heating and cooling systems (HVAC), and/or inadequate air sealing)
	Appliances and lighting efficiency (e.g., large-scale appliances such as refrigerators, washing machines, and dishwashers)
	Topography and location (e.g., climate, urban heat islands)
	Climate change and weather extremes that raise the need for heating and cooling
Socioeconomic	Chronic economic hardship due to persistent low income
	Sudden economic hardship (e.g., severe illness, unemployment, or disaster event)
	Inability to afford (or difficulty affording) up-front costs of energy efficiency investments
	Difficulty qualifying for credit or financing options to make efficiency investments due to financial and other systemic barriers
	Systemic inequalities relating to race and/or ethnicity, income, disability, and other factors
Behavioral	Information barriers relating to available bill assistance and energy efficiency programs and relating to knowledge of energy conservation measures
	Lack of trust and/or uncertainty about investments and/or savings
	Lack of cultural competence in outreach and education programs
	Increased energy use due to occupant age, number of people in the household, health-related needs, or disability
Policy-related	Insufficient or inaccessible policies and programs for bill assistance, energy efficiency, and weatherization for low-income households
	Utility rate design practices, such as high customer fixed charges, that limit customers' ability to respond to high bills through energy efficiency or conservation

Source: Updated from Ross, Drehobl, and Stickles 2018

Drivers of high household energy burdens are often the result of the systemic factors, barriers, and challenges that these households face. Previous research identified drivers that can raise energy burdens, including the dwelling's physical structure, the resident's socioeconomic status and behavioral patterns, and the availability of policy-related resources (Drehobl and Ross 2016; Ross, Drehobl, and Stickles 2018). Table 1 shows an updated list of key drivers of high energy burdens.

ENERGY INEFFICIENCY AS A DRIVER OF HIGH ENERGY BURDENS

While low incomes are a substantial factor driving higher energy burdens, inefficient housing is also a contributor. According to the 2017 AHS data, 9% of total U.S. households completed an energy-efficient improvement in the past two years, but only 17% were low-income households (Census Bureau 2019). Low-income households (≤ 200% of the federal poverty level [FPL]) make up about 30% of the population, which means that they are underrepresented in households completing energy efficiency upgrades and thus are not proportionally accessing and benefiting from these investments.

Additional research examining energy benchmarking data in a few major cities has found that households from both the lowest- and highest-income brackets had the highest *energy use intensity* (EUI)—that is, they had the highest energy consumption per square foot. While consumption behaviors are regarded as the driver for high EUI among higher-income households, the researchers point to inefficient heating and lighting infrastructure to help explain the high EUI among low-income households (Kontokosta, Reina, and Bonczak 2019). High-income households use large amounts of energy to power larger homes—as well as more electronics and devices that use large amounts of energy—while low-income households tend to use fewer, less-efficient devices that require relatively large amounts of energy due to the inefficiency of the dwelling or the appliance itself. Therefore, household inefficiencies rather than inefficient behaviors tend to lead to higher energy use and expenditures for low-income households. Generally, energy efficiency investments can allow households to engage in the same activity while using less energy, thus reducing high energy burdens and improving comfort, health, and safety.

Adverse Effects of High Energy Burdens

Our comprehensive evaluation of energy burden research reveals both that low-income households spend, on average, a higher portion of their income on energy bills than other groups, and that energy burdens are also higher for communities of color, rural communities, families with children, and older adults (Brown et al. 2020; Lewis, Hernández, and Geronimus 2019; Reames 2016; Hernández et al. 2016; Drehobl and Ross 2016; Ross, Drehobl, and Stickles 2018). Energy burden is one indicator to measure energy insecurity, and high energy burdens are associated with inadequate housing conditions and have been found to affect physical and mental health, nutrition, and local economic development.

EXCESSIVE ENERGY COST CAN IMPACT RESIDENTS' HEALTH AND COMFORT.

Researchers have found that many households with high energy burdens also live in older, inefficient, and unhealthy housing. Inefficient housing is associated with other health impacts, such as carbon monoxide poisoning, lead exposure, thermal discomfort, and respiratory problems such as asthma and chronic obstructive pulmonary disease (COPD); it is also associated with the potential for hypothermia and/or heat stress resulting from leaky and/or unrepaired heating and cooling equipment (Brown et al. 2020; Norton, Brown, and Malomo-Paris 2017).

Households experiencing energy insecurity may forego needed energy use to reduce energy bills, forcing them to live in uncomfortable and unsafe homes. Hernández, Phillips, and Siegel (2016) found that half of the study's participants who experienced high monthly utility bills engaged in coping strategies such as using secondary heating equipment (i.e., stoves, ovens, or space heaters) to compensate for inefficient or inadequate heating systems. Employing this coping measure can compromise resident safety and comfort, and it may increase exposure to toxic gases. Teller-Elsberg et al. (2015) found that excess winter deaths potentially caused by fuel poverty kill more Vermonters each year than car crashes. In addition, according to the Residential Energy Consumption Survey, one in five U.S. households reported reducing or forgoing necessities such as food or medicine to pay an energy bill (EIA 2018). These tradeoffs can impact long-term health and well-being.

Climate change, rising temperatures, and subsequent cooling demands will continue to exacerbate household energy burdens—and prove deadly for some. In Maricopa County, Arizona—one of the hottest regions in the southwest—more than 90% of residents have access to a cooling system, yet up to 40% of heat-related deaths occur indoors (Maricopa County Department of Public Health 2020). A recent survey of homebound individuals found that one-third faced limitations on home cooling system use, with the overwhelming majority (81%) citing the "cost of bills" as a contributing factor (Maricopa County Department of Public Health 2016). As residents are increasingly forced to weigh the cost of properly cooling their homes, high energy burdens will likely become an even greater public health priority in the years to come.

HIGH ENERGY BURDENS IMPACT MENTAL HEALTH OF RESIDENTS.

High energy burdens can have mental health impacts—such as chronic stress, anxiety, and depression—associated with fear and uncertainty around access to energy, the complexities of navigating energy assistance programs, and the inability to control energy costs (Hernández, Phillip, and Siegel 2016). In addition, Hernández (2016) found that low-income residents who were experiencing energy insecurity worried about losing their parental rights as they struggled to maintain essential energy services, such as lighting, in their homes.

HIGH ENERGY BURDENS CAN LIMIT INDIVIDUALS' ABILITY TO BENEFIT FROM ECONOMIC DEVELOPMENT IN THEIR COMMUNITIES.

Households with high energy burdens are more likely to stay caught in cycles of poverty. After controlling for common predictors of poverty status such as income loss, illness, health, marital status, education, health insurance, and head of households—Bohr and McCreery (2019) found that, on average, energy-burdened households have a 175–200% chance of remaining in poverty for a longer period of time compared to nonenergy-burdened households.[11] BIPOC communities, older adults, and low-income households often experience this pernicious cycle, which includes persistent income inequality along with limited funding to invest in education or job training, and high energy burdens can perpetuate this cycle (Bohr and McCreery 2019; Lewis, Hernández, and Geronimus 2019).

Households with high energy burdens are more likely to stay caught in cycles of poverty.

Impact of COVID-19 on Energy Insecurity

As the world enters a global recession in the wake of the coronavirus pandemic, more households—especially in BIPOC communities—may have difficulty paying their energy bills due to massive job losses; reduced income; a warming climate; and higher energy bills resulting from more time at home due to stay-at-home orders and to students and adults learning and working from home, respectively. For example, in March and April 2020, the California Public Utility Commission stated that residential electricity usage increased by 15–20% compared to the previous year (CPUC 2020). Because such factors lead to higher home energy bills, energy burdens will increase for households across the United States.

COVID-19 disproportionally impacts BIPOC communities due to many of the policies that have led to systemic economic and social exclusion. These policies have led to BIPOC communities experiencing higher rates of underlying health conditions, a lack of health insurance or access to testing, and a higher likelihood of working in the service industry or in other essential worker roles that do not allow for teleworking (SAMHSA 2020; CDC 2020). COVID-19 has also impacted the ability of energy efficiency and weatherization programs to operate, and limited the mix of measures that can be installed; many energy efficiency and weatherization programs have slowed down or are on hold (Ferris 2020). Policies and programs that address energy insecurity are even more important now in the face of rising energy bills and burdens.

Given these factors, energy burdens in 2020 are likely to be much higher than the burdens we calculate in this report, which uses 2017 data. The economic situation has clearly shifted drastically since 2017. While we expect post-2020 burden trends to be similar, yet more acute, we cannot visualize the full extent of current and future energy burdens until the release of post-2020 data in the 2023 AHS, which will include data from 2021.

[11] This study does not examine the relationship between energy burden and rent burden (i.e., the percentage of income spent on housing costs). Studies have found that rent burdens are also increasing, especially for communities of color, older adults, and families (Currier et al. 2018).

Methods

This analysis builds on the methods used in ACEEE's previous two energy burden studies, *Lifting the High Energy Burden in American's Largest Cities* (Drehobl and Ross 2016) and *The High Cost of Energy in Rural America* (Ross, Drehobl, and Stickles 2018). This new study analyzes 2017 data from AHS, which is issued by the U.S. Department of Housing and Urban Development (HUD). The AHS is a biennial household-level survey by the Census Bureau that collects wide-range housing and demographic data from a nationally and regionally representative cross section of households across the United States and in a subset of metropolitan statistical areas (MSAs). The AHS includes household-level income data and energy cost data that we use as the basis of our energy burden calculations. The AHS models its energy cost data based on household characteristics ascertained through its survey and also uses data collected through the Residential Energy Consumption Survey (RECS) for a different national set of households.[12]

As we noted earlier, we define households with high energy burdens as those spending more than 6% of their income on electricity and heating fuel costs, and households with severe energy burdens as those spending more than 10% of their income on energy costs.[13] These two categories are not mutually exclusive; *severe burden* is a worse-off subset of high burden households.

[12] Beginning with the 2015 edition, the AHS stopped including questions on energy costs. Previously, the majority of these data was self-reported. As part of the 2015 AHS redesign, researchers began estimating energy costs through regression-model–based imputation. They created the utility estimation system (UES) to estimate annual energy costs using regression models developed from the RECS, which collects administrative data from suppliers on actual billing amounts. This estimate was divided by 12 to calculate average monthly energy costs. The RECS also collects some housing characteristics similar to those the AHS collects, which allows the construction of models that can then be applied to the AHS. For more on the energy cost estimation model development and decisions for the 2015 AHS, see www.huduser.gov/portal/sites/default/files/pdf/American-Housing-Survey.pdf.

[13] HUD determines affordable housing costs to be 30% of total household income. Researchers have determined that, typically, 20% of total housing expenses are energy costs. This equates to 6% of total income spent on energy bills as an affordable level (Fisher Sheehan & Colton 2020). We consider energy burdens above 6% to be high burdens, with burdens above 10% to be severe. This method is in line with other research (APPRISE 2005).

The following are our study's inclusion and exclusion criteria:

- *Electricity and heating fuels*. The study does not include water, transportation, telecommunications, or Internet costs. Although such costs can create additional monetary burdens for households, we include only electricity and heating fuel costs in our energy burden calculations.

- *Households must report household income and the amount they pay for their electricity and their main heating fuel*.[14] If households did not include all three factors, we did not include them in our analysis.

We examine energy burdens for a variety of household subsets at the national, regional, and metropolitan levels, including the following:

- *Income level*. All households that fall into low-income (≤ 200% FPL) and non-low-income (> 200% FPL) categories.[15]

- *Low-income households with vulnerable persons at home*. Low-income households with a household member over the age of 65, under the age of 6, or who has a disability.

- *Housing type and age*. Single-family, small multifamily (two to four units), large multifamily (five or more units), low-income multifamily (five or more units and ≤ 200% FPL), manufactured housing, buildings built before 1980, and buildings built after 1980.[16]

- *Tenure*: Renters and owners.

- *Race and ethnicity*. Black, Hispanic, and non-Hispanic white households. We also include Native American households in the national analysis.

- *Age*. Households with one or more adults over the age of 65.

Limitations

We included 48 MSAs in our last urban energy burden report, which used both 2011 and 2013 AHS data. This report uses only 2017 data, which limits our sample to 25 MSAs (AHS 2019). AHS includes modeled energy costs, which are determined by matching characteristics of households in the AHS to characteristics of households in the RECS. We also exclude households that do not report income, do not have a heating source, or do not pay for their heating costs. Thus, our report findings do not include data on renters who pay for their heating and/or electricity in their rent, or households with no annual income reported.

Our study does not explore causality, so we cannot determine *why* energy burdens differ across metro areas and demographic and other groups. Additional research is needed to determine the causes of disproportionate energy burdens, which can include building efficiency, income and poverty rates, and other timely economic factors. We are unable to compare trends across our energy burden reports, as this study does not explore why and how energy burdens may have changed over time.

Finally, our study includes only the 25 metro areas sampled by the AHS, which are not necessarily the best or worst performing metro areas regarding energy burdens. Ranking metro areas is thus limited since this is only a partial sample of cities. ACEEE plans to update this research with additional metro areas as more AHS data are available in the fall of 2020.

The following are the 25 MSAs with representative samples in the 2017 AHS dataset:

1. Atlanta	6. Dallas	11. Miami	16. Phoenix	21. San Francisco
2. Baltimore	7. Detroit	12. Minneapolis	17. Richmond	22. San Jose
3. Birmingham	8. Houston	13. New York City	18. Riverside	23. Seattle
4. Boston	9. Las Vegas	14. Oklahoma City	19. Rochester	24. Tampa
5. Chicago	10. Los Angeles	15. Philadelphia	20. San Antonio	25. Washington, DC

[14] AHS calculates household income as total money before taxes and other payments, including Social Security income, cash public assistance, or welfare payments from the state or local welfare office, retirement, survivor or disability benefits, and other sources of income such as veterans' payments, unemployment and/or worker's compensation, child support, and alimony. For more information, see: www2.census.gov/programs-surveys/ahs/2017/2017%20AHS%20Definitions.pdf.

[15] In ACEEE's 2016 urban energy burden report, we defined low-income as 80% of the area median income (AMI), while this report defines low-income as 200% FPL. We made this change due to data availability. The 200% FPL definition also lines up with the Weatherization Assistance Program and is the most common qualification criterion for utility-led low-income programs. Because of this, low-income data in the 2016 and 2020 reports do not use the same definitions and are therefore not directly comparable.

[16] We chose 1980 as our cutoff point as states and cities began adopting the first building energy codes in the late 1970s and early 1980s. At this time, builders around the country began to consider energy and minimal energy efficiency measures due to increasing awareness of efficiency measures and concerns about energy as a result of the energy-related economic shocks of the 1970s.

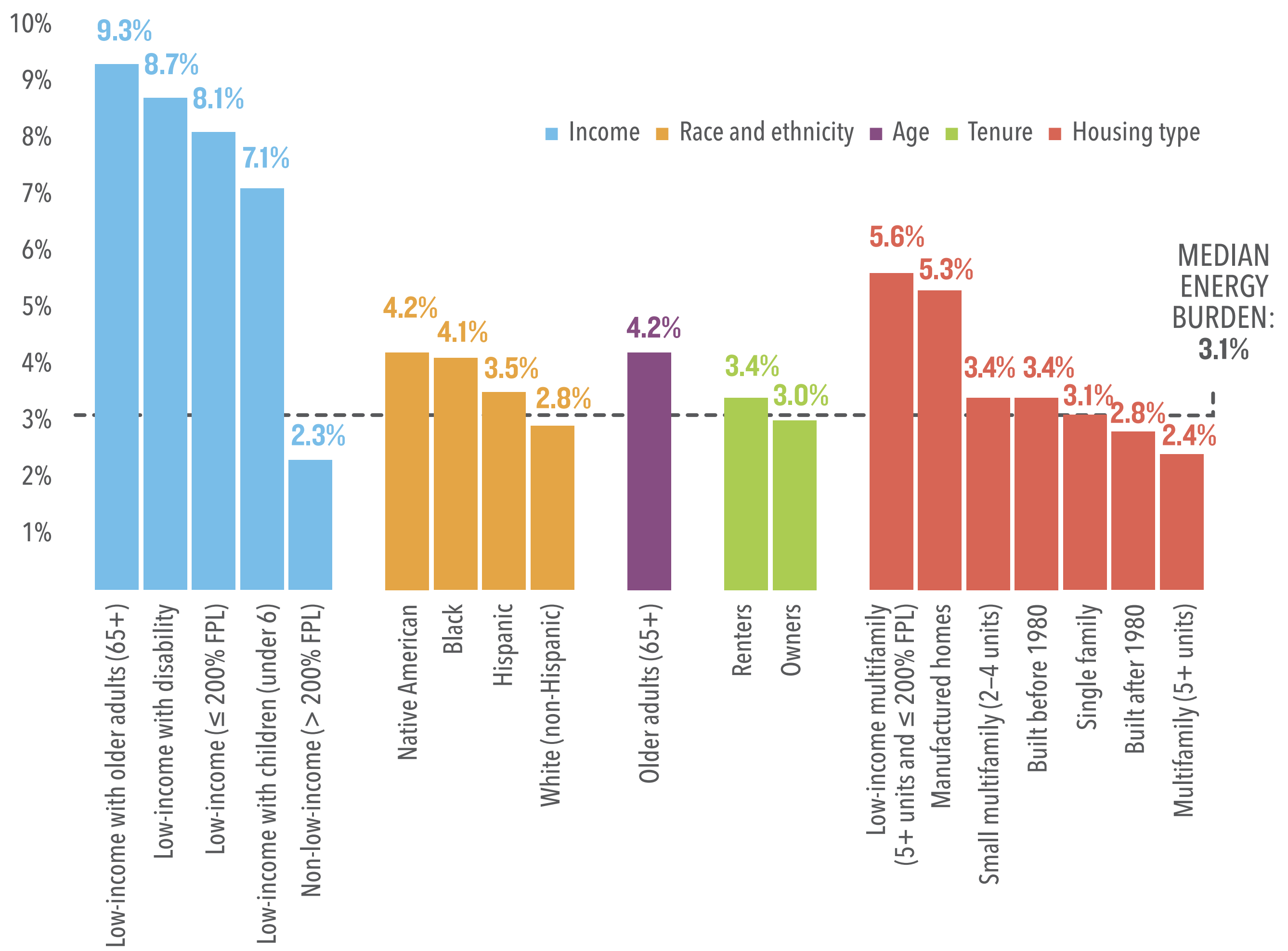
Energy Burden Findings

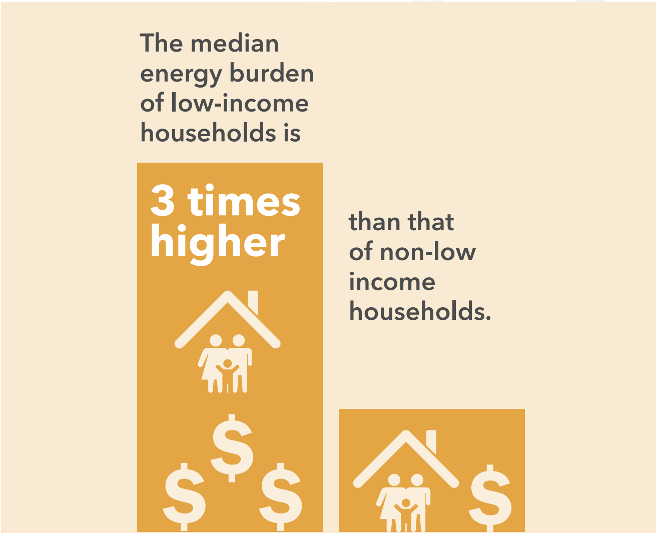
The results of this energy burden analysis reflect previous ACEEE studies in finding that nationally, regionally, and across all 25 metro areas, particular groups experience disproportionately high energy burdens. See **Appendices A** and **B** for tables including national, regional, and metro energy burden data.

National Energy Burdens

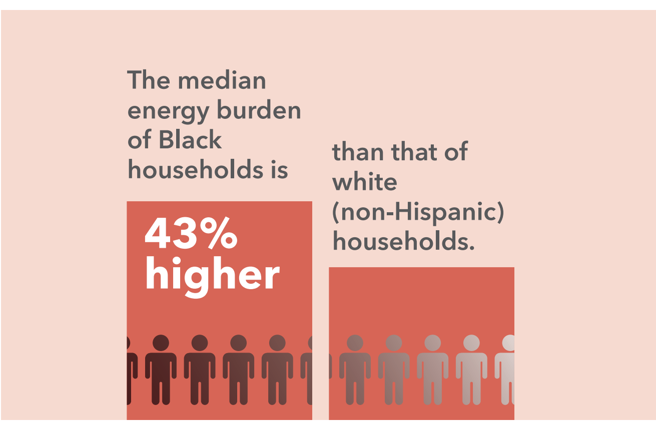
Across the nationally representative sample, we find that low-income, Black, Hispanic, renter, and older adult households have disproportionately higher energy burdens than the average household. Figure 1 shows the median energy burden for different groups nationally, across categories of income, race and ethnicity, age, tenure status, and housing type. We find that the median national energy burden is 3.1%, and that the median low-income (≤ 200% FPL) household energy burden is 3.5 times higher than the non-low-income household energy burden (8.1% versus 2.3%).

FIGURE 1. National energy burdens across subgroups (i.e., income, race and ethnicity, age, tenure, and housing type) compared to the national median energy burden

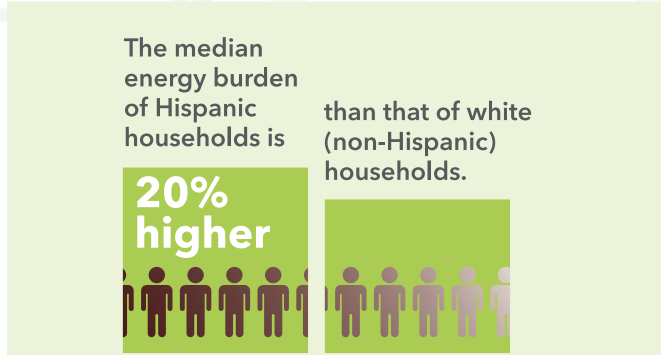




Many groups experience disproportionately high energy burdens, with low-income households having the highest energy burdens. These households have limited discretionary income and often have older, less-efficient housing stock and appliances that lead to higher energy bills. Even for cases in which monthly energy costs are similar between low-income and non-low-income households, the former devote a greater proportion of their income to these costs. Given this, reducing excess energy use in low-income households is critical for addressing energy insecurity.



We also recognize that many highly burdened groups are intersectional—that is, they face compounding, intersecting causes of inequality and injustice. For example, nearly half of the older adult population in general is economically vulnerable, as are the majority of older Black and Hispanic households (Cooper and Gould 2013). Policies and programs that focus on addressing low-income household energy burdens will likely intersect with other highly burdened groups. Further research can help identify how high energy burdens are impacted by differences in race, ethnicity, income, education, housing type, occupant age, and other factors.



NATIONAL DATA: HIGH AND SEVERE ENERGY BURDENS

Median energy burdens allow us to compare burdens between groups, yet they do not illustrate how many people experience the impacts of energy insecurity, or the degrees to which they experience it. We therefore also calculate the percentage of households that experience high and severe energy burdens for different demographic groups. Figure 2 shows the percentage of households across subgroups that experience a high energy burden (above 6%), along with the total number of households experiencing a high energy burden. Figure 2 also indicates the percentage of those households that experience a severe energy burden (above 10%).

Nationally, more than 25% (30.6 million) of all households experience a high energy burden, and about 50% (15.9 million) of all households that experience a high energy burden have a severe energy burden. These burdens are even more acute for low-income households, of which 67% (25.8 million) experience a high energy burden and 60% (15.4 million) of those experience a severe energy burden. **Appendix B** includes high and severe energy burden percentages and total households that experience a high and severe

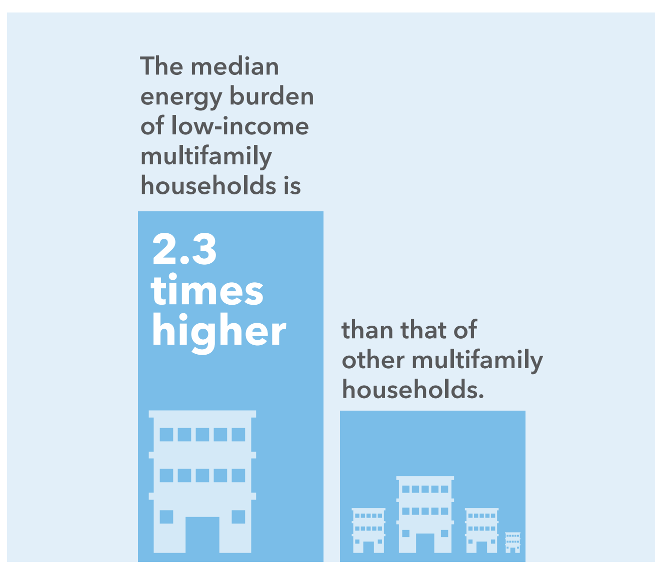
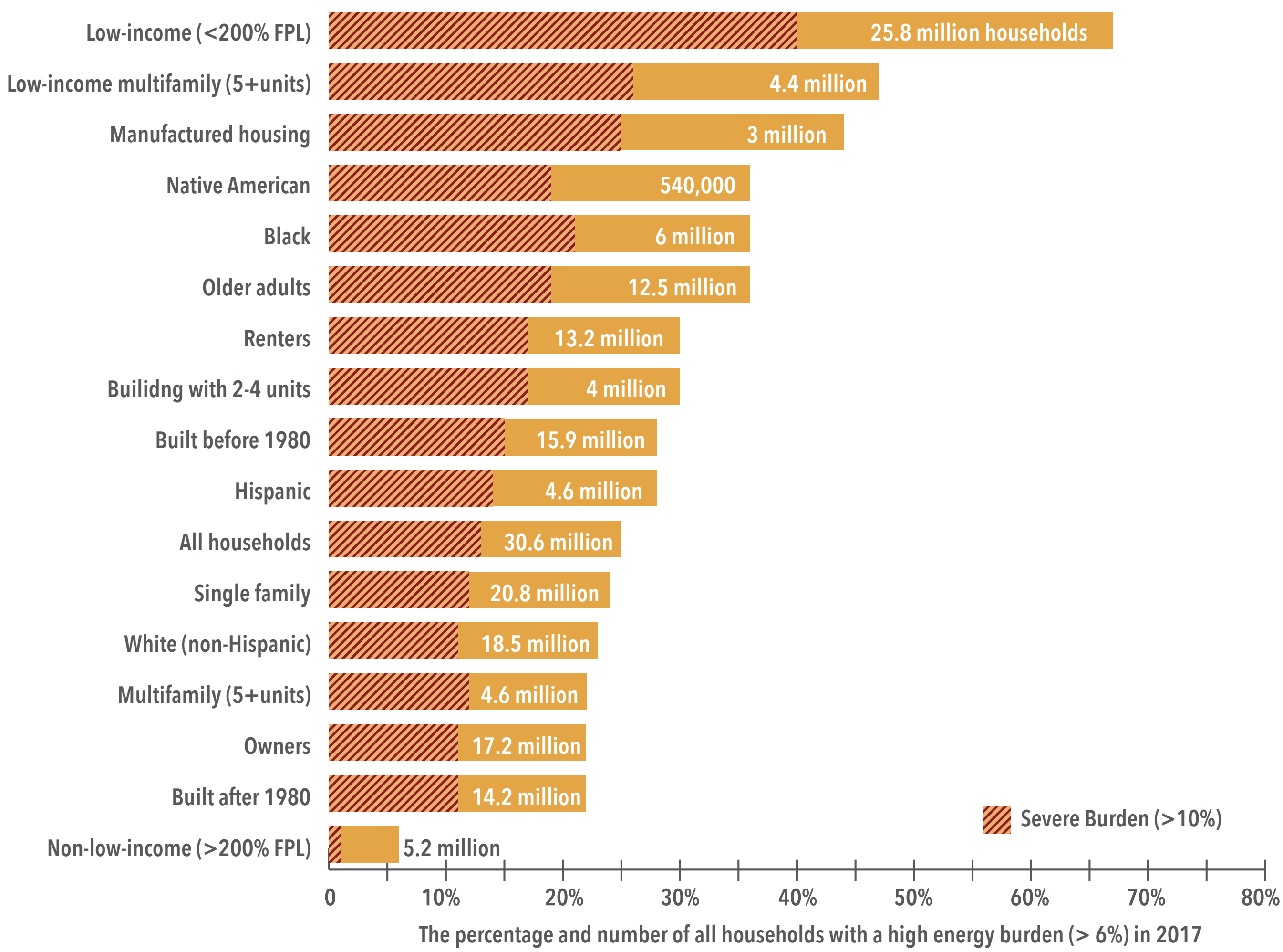


FIGURE 2. The percentage and number of households nationally with a high energy burden (> 6%) across different subgroups in 2017

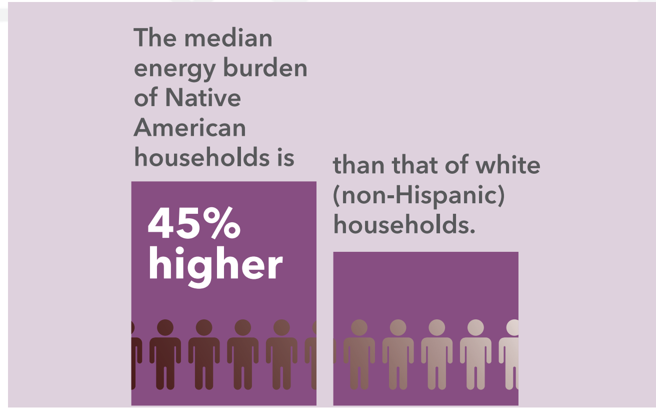


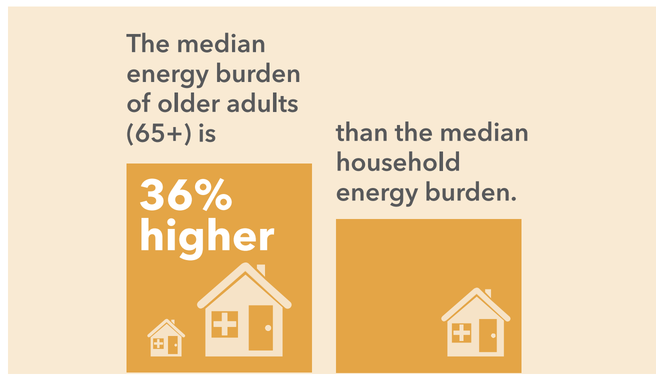
Note: High and severe energy burdens are not mutually exclusive, meaning that the number of households experiencing a severe burden are also counted in the percentage that experience high burdens. All severe energy burdens (> 10%) also fall into the high burden category (> 6%). The red and orange bars in figure 2 sum to the total high energy burdened households, and the number of households is the total that experience a high energy burden.

burden nationally, regionally, and in each MSA across all households and across low-income, Black, Hispanic, older adult, and renting households.

As figure 2 illustrates, U.S. residents experience high and severe energy burdens at different rates depending on factors such as income, occupant age, race, and tenure. Almost 50% of low-income multifamily residents; 36% of Black, Native American, and older adult households; 30% of renters; and 28% of Hispanic households experience a high energy burden.

Many households also have severe energy burdens, spending more than 10% of their income on energy. For example, 21% of Black households experience severe energy burdens as compared to 1% of non-low-income and 9% of non-Hispanic white households. For context, households with severe energy burdens spend at least three times more of their income on home energy bills than the median household.





Regional Energy Burdens

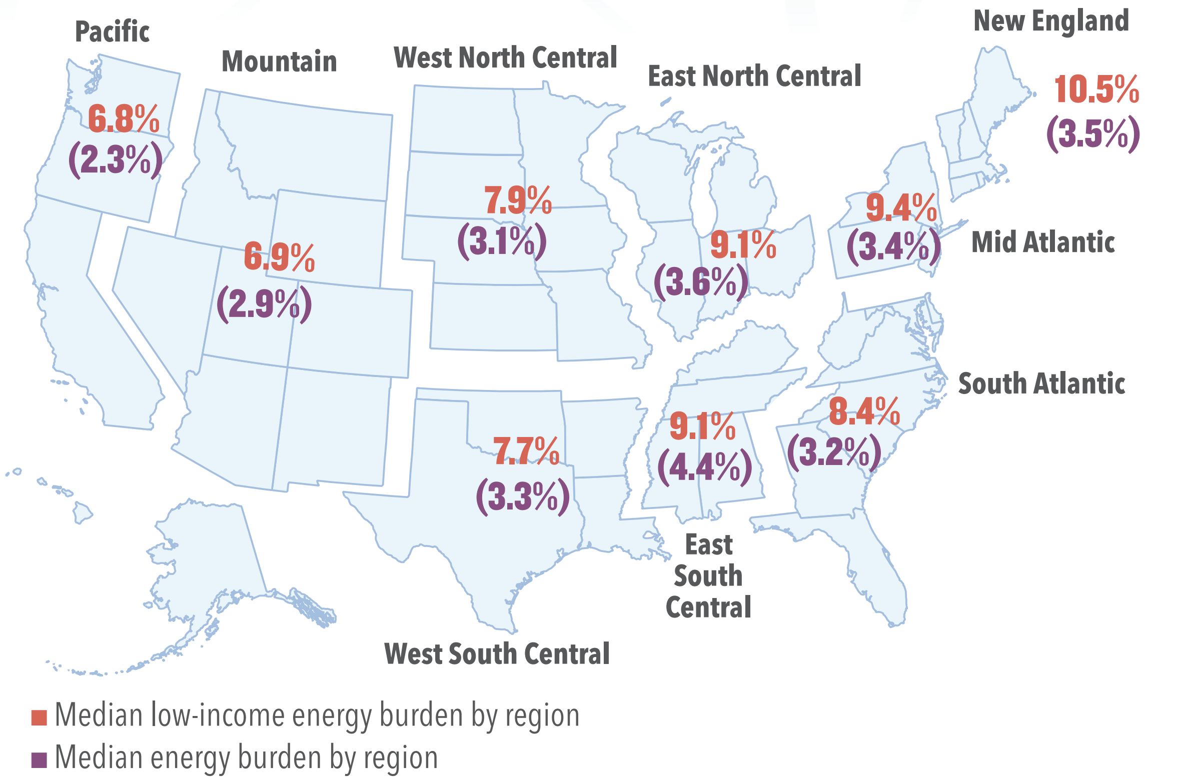
National patterns play out across all regions, where low-income, Black, and Hispanic households; renters; manufactured housing residents; and older adults all have disproportionately higher energy burdens than each region's average household. Table 2 shows the states in each census region in the study.

Across all nine regions, low-income household energy burdens are 2.1–3 times higher than the median energy burden. The gap between low-income and median energy burdens is largest in the New England, Pacific, and Mid-Atlantic regions (3.0, 2.9, and 2.8 times higher, respectively). Figure 3 illustrates low-income energy burdens and the median energy burden across the nine census regions.

TABLE 2. States within each census region

Region	States
New England	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Middle Atlantic	New Jersey, New York, Pennsylvania
East North Central	Illinois, Indiana, Michigan, Ohio, Wisconsin
West North Central	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
South Atlantic	Delaware, DC, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia
East South Central	Alabama, Kentucky, Mississippi, Tennessee
West South Central	Arkansas, Louisiana, Oklahoma, Texas
Mountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
Pacific	Alaska, California, Hawaii, Oregon, Washington

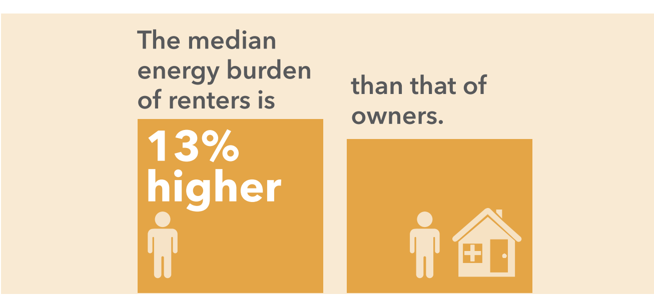
FIGURE 3. Median low-income (< 200% FPL) energy burdens by region (red) compared to median energy burdens by region (purple)



REGIONAL DATA: HIGH AND SEVERE ENERGY BURDENS

Figure 4 shows the percentage and total number of households that experience high and severe energy burdens in each region.

The percentage and total number of households that experience a high energy burden vary across regions. The East South Central region has the greatest percentage of households with high energy burdens (38%), followed by East North Central, New England, and Middle Atlantic regions, all with 29%. The South Atlantic region had the greatest number of households (6.27 million) with high burdens, followed by the East North Central (5.40 million) and Middle Atlantic (4.57 million) regions. See **Appendix B** for the total number of highly burdened households across different groups in each region.

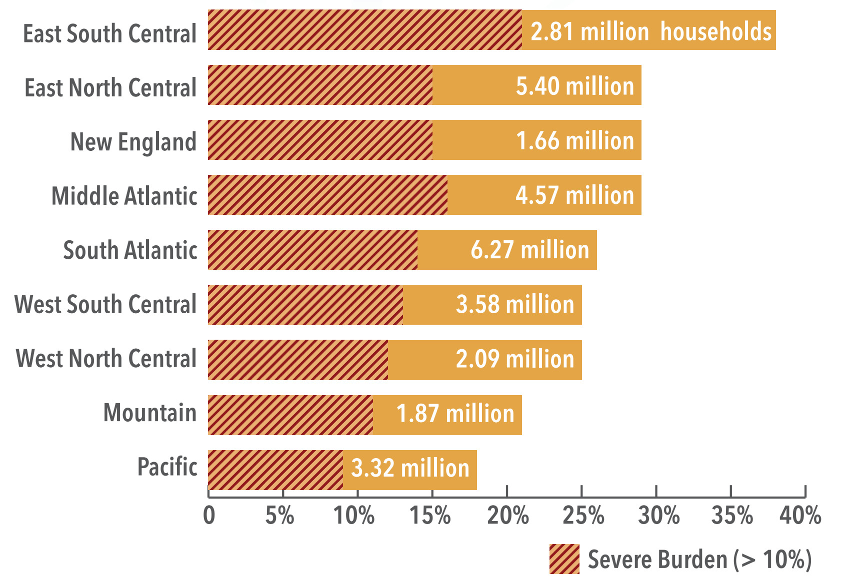


Metro Area Energy Burdens

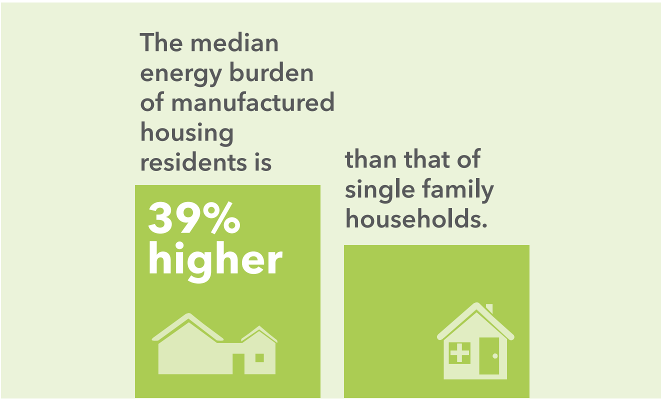
Across the select MSAs—which represent 38% of all households nationally—low-income households, low-income multifamily households, and older adult households are the most energy burdened groups. Groups with the lowest energy burdens are non-low-income, those living in buildings built after 1980, and those living in market-rate multifamily housing. Table 3 includes the median energy burdens for the most highly burdened groups in each metro area; **Appendices A** and **B** offer more details.[17]

[17] **Appendix A** includes national, regional, and metro area sample sizes, median energy burdens, median incomes, median monthly bills, upper-quartile energy burdens, percentage with a high burden, and percentage with a severe burden. **Appendix A** also includes median and upper-quartile energy burdens for subgroups nationally, regionally, and in metro areas, including low-income, low-income with older adults, low-income with a child under 6, low-income with disability, low-income multifamily, non-low-income, Black, Hispanic, non-Hispanic white, older adult, renters, owners, multifamily, built before 1980, and built after 1980. **Appendix B** includes the number of households nationally, regionally, and in metro areas that experience a high or severe energy burden.

FIGURE 4. The percentage and number of all households with a high energy burden (> 6%) in each region in 2017



The percentage and number of all households with a high energy burden (> 6%) in 2017



Across the 25 MSAs, low-income households experience energy burdens at least two times higher than the average household in all cities. In all metro areas, Black and Hispanic households experience higher energy burdens than non-Hispanic white households. Renters and people living in buildings built before 1980 experience higher energy burdens than owners in almost all metro areas in the study.

Median energy burdens do not tell the whole energy affordability story, as half of households in each group experience a higher energy burden than the median.

Figure 5 includes the energy burdens at the median and upper quartile, showing that 50% of households in each city experience a burden above the median and 25% experience a burden above the upper quartile. For example, in Baltimore, 25% of low-income households experience an energy burden above 21.7%, which is seven times the national median burden. In five cities—Baltimore, Philadelphia, Detroit, Boston, and Birmingham—a quarter of low-income households have energy burdens above 18%, which is three times the 6% high energy burden threshold.

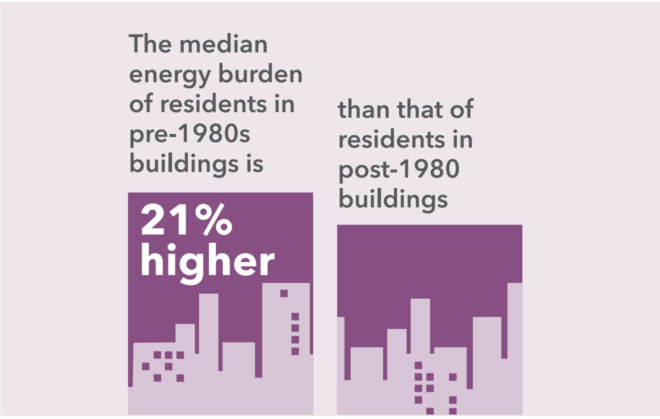
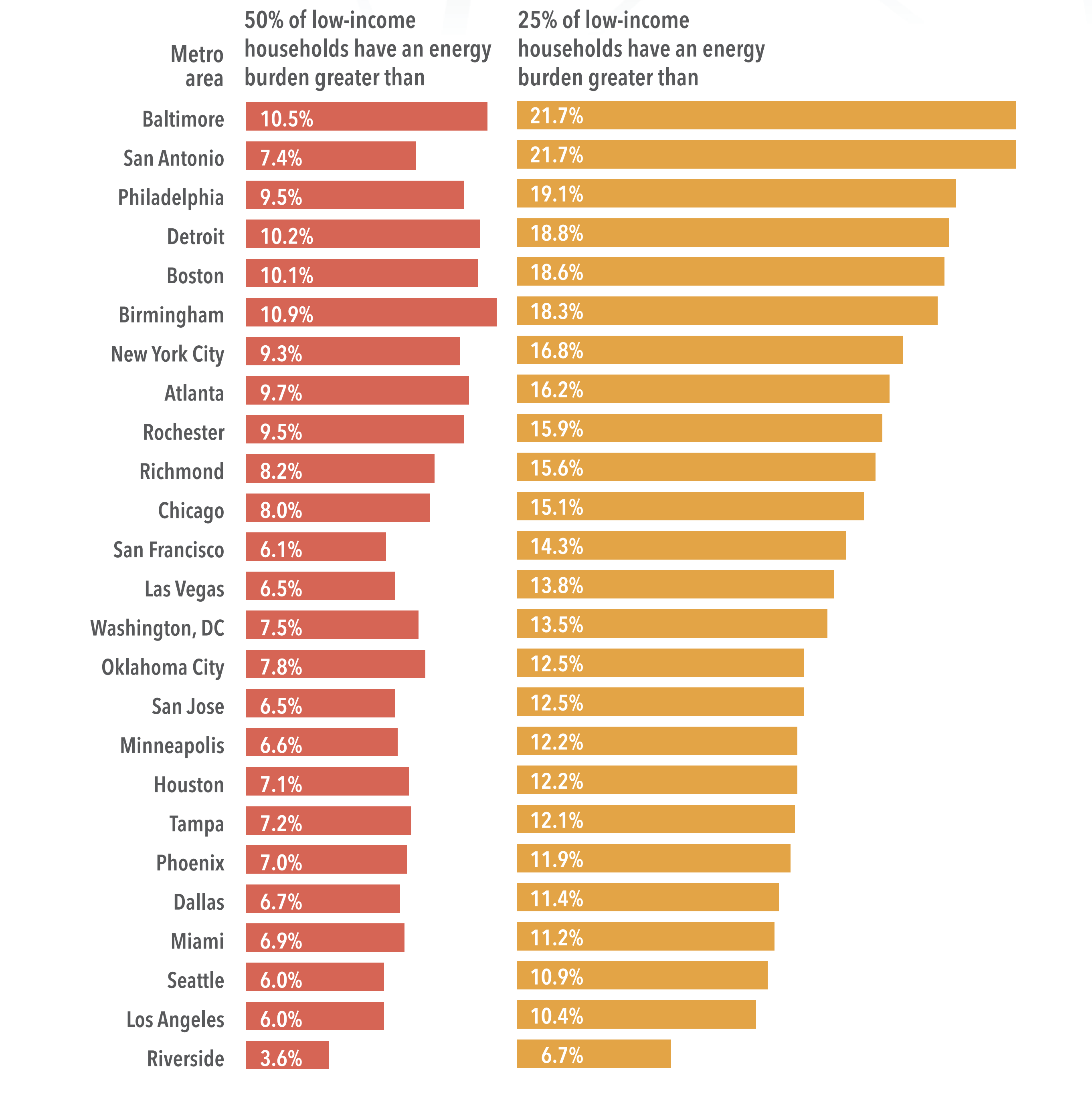


TABLE 3. Median energy burdens in metro areas for all households and highly impacted groups, including low-income, Black, Hispanic, older adult (65+), renters, low-income multifamily residents, and those residing in buildings built before 1980

Metro area	All households	Low-income (≤ 200% FPL)	Black	Hispanic	Older adults (65+)	Renters	Low-income multifamily*	Built before 1980
National data	3.1%	8.1%	4.2%	3.5%	4.2%	3.4%	3.1%	3.4%
Atlanta	3.5%	9.7%	4.1%	4.7%	5.1%	3.7%	6.6%	4.5%
Baltimore	3.0%	10.5%	3.8%	3.3%	4.1%	3.2%	2.5%	3.6%
Birmingham	4.2%	10.9%	5.6%	4.8%	5.8%	5.2%	6.8%	5.1%
Boston	3.1%	10.1%	3.7%	3.6%	4.4%	3.2%	6.6%	3.2%
Chicago	2.7%	8.0%	4.1%	3.0%	3.7%	3.1%	6.4%	2.9%
Dallas	2.9%	6.7%	3.3%	3.8%	3.8%	2.9%	5.0%	3.5%
Detroit	3.8%	10.2%	5.3%	4.5%	5.2%	4.6%	6.0%	4.3%
Houston	3.0%	7.1%	3.5%	3.4%	4.1%	3.3%	5.8%	3.4%
Las Vegas	2.8%	6.5%	3.2%	3.0%	3.4%	3.0%	5.3%	3.6%
Los Angeles	2.2%	6.0%	3.6%	2.6%	3.2%	2.4%	4.8%	2.3%
Miami	3.0%	6.9%	3.4%	3.1%	4.2%	3.1%	5.5%	3.3%
Minneapolis	2.2%	6.6%	2.6%	2.7%	3.0%	2.3%	4.3%	2.5%
New York City	2.9%	9.3%	3.6%	3.8%	4.2%	3.3%	8.0%	3.0%
Oklahoma City	3.3%	7.8%	3.9%	4.2%	4.0%	3.9%	6.5%	3.8%
Philadelphia	3.2%	9.5%	4.4%	5.2%	4.4%	3.9%	6.5%	3.6%
Phoenix	3.0%	7.0%	3.2%	3.6%	4.0%	2.8%	4.6%	3.6%
Richmond	2.6%	8.2%	3.4%	2.9%	3.5%	2.9%	5.0%	3.1%
Riverside	3.6%	8.7%	3.9%	3.7%	5.1%	4.0%	6.1%	4.3%
Rochester	3.8%	9.5%	5.1%	5.4%	4.8%	4.3%	6.0%	4.0%
San Antonio	3.0%	7.4%	3.1%	3.4%	4.1%	3.1%	4.8%	3.9%
San Francisco	1.4%	6.1%	2.4%	1.2%	2.4%	1.4%	4.9%	1.4%
San Jose	1.5%	6.5%	1.8%	1.9%	2.4%	1.5%	4.7%	1.6%
Seattle	1.8%	6.0%	2.3%	2.0%	2.4%	1.8%	4.1%	2.0%
Tampa	2.8%	7.2%	3.6%	3.5%	3.8%	2.8%	4.9%	3.3%
Washington, DC	2.0%	7.5%	2.9%	2.7%	2.9%	2.0%	5.2%	2.3%

* Low-income multifamily households are below 200% FPL and in a building with five or more units.

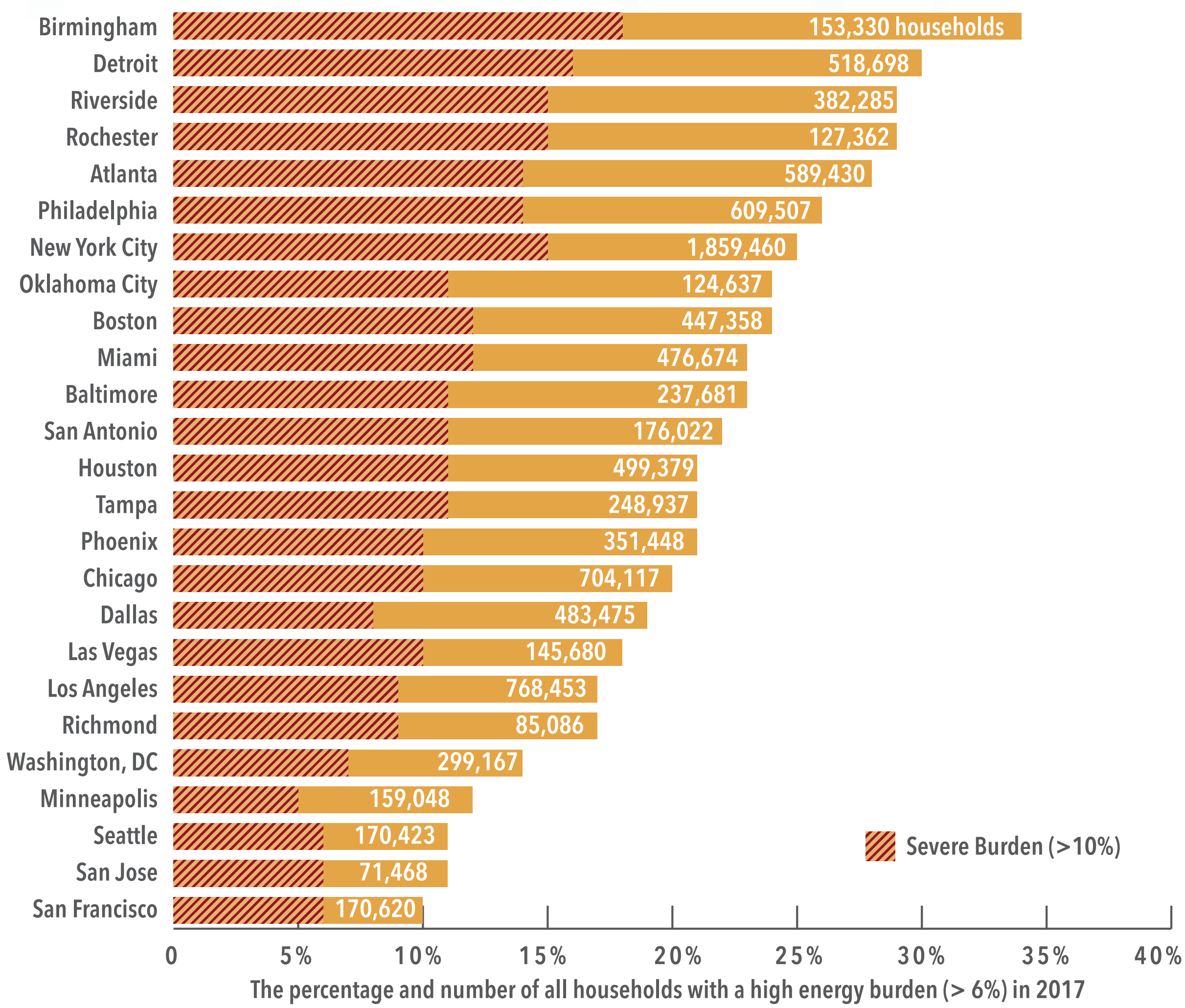
FIGURE 5. Energy burden experienced by 50% and 25% of low-income households in 25 metro areas



METRO DATA: HIGH AND SEVERE ENERGY BURDENS

The percentage of households experiencing a high energy burden varied across the select metro areas, with up to one-third of residents in some cities facing a high energy burden. Figure 6 shows the percentage and total number of households in each metro area that experience high and severe energy burdens. Six metro areas have a greater percentage of households with a high energy burden than the national average (25%), including Birmingham (34%), Detroit (30%), Riverside (29%), Rochester (29%), Atlanta (28%), and Philadelphia (26%).

FIGURE 6. The percentage and number of all households with a high energy burden (> 6%) in each of the 2017 AHS MSAs



Appendix B includes data on high and severe energy burdens in each metro area in our sample. In nine metro areas, 12% or more of households experienced a severe energy burden, spending more than 10% of their income on energy bills; among these are 1.1 million households in New York City, 333,000 in Philadelphia, and 288,000 in Atlanta.

As these findings illustrate, high and severe energy burdens are both a national and a local challenge. Even though some metro areas have lower percentages of households with high energy burdens than the national average, each city has tens to hundreds of thousands of households with high energy burdens. In addition, both the national energy burden trends and the metro-level trends show similar patterns of energy burden vulnerability for specific groups and are therefore likely reflected in other metro areas nationally as well. This indicates that both the metro areas studied and other cities have energy burden disparities in their communities. They also have opportunities to create policy and programs to lower these energy burdens for their residents.

By focusing on the needs of those who are disproportionally burdened—particularly at the intersection of criteria such as of low-income, communities of color, older adults, and renters—policymakers can set policies and create programs that have the greatest impact on energy insecurity. As they do so, they should recognize that many households—especially those with high energy use due to building inefficiencies—experience much higher than average energy burdens. These households are therefore likely to need targeted and long-lasting interventions, such as energy efficiency and weatherization, to achieve long-term affordability.

Low-Income Weatherization Can Reduce High Energy Burdens

Energy efficiency and weatherization provide a long-term solution to reducing high energy burdens, while also complementing bill payment assistance and programs aimed at energy-saving education and behavior change. *Weatherization* refers to programs that address the efficiency of the building envelope and building systems (such as unit heating, cooling, lighting, windows, and water heating) through energy audits; these audits identify cost-effective energy efficiency upgrades provided through energy efficiency programs. Other low-income energy efficiency programs may include additional measures such as appliance replacements, efficient lighting, and health and safety measures. While these recommendations focus on weatherization and energy efficiency as a long-term solution to reducing high energy burdens, these investments can be combined with renewable energy technologies and/or electrification strategies to further reduce energy bills.

Energy efficiency programs and investments that provide comprehensive building upgrades—such as insulation, air sealing, heating and cooling systems, appliances, lighting, and other baseload measures—can strongly impact long-term energy affordability, as low-income households tend to live in older buildings and have older, less-efficient appliances than higher income households (Cluett, Amann, and Ou 2016). Research suggests that weatherization measures can reduce energy use by 25–35% (DOE 2014, 2017; DOE 2011). Assuming a 25% reduction in energy use and using the 2017 AHS data, we estimate that energy efficiency and weatherization can reduce the energy burden of the average low-income household by 25%.[18]

Low-income energy efficiency and weatherization programs are especially important in the wake of the economic recession and pandemic. These programs can both reduce high energy burdens and help stimulate the economy through local job creation and workforce development. Policies that accelerate investment in, improve the design of, and better target low-income energy efficiency, weatherization, and housing retrofit programs can have a high impact on long-term energy affordability.

[18] We assume a 25% savings from energy efficiency upgrades based on the U.S. Department of Energy's estimate (DOE 2014) and use the median low-income household values to calculate a 25% reduction. We reduced the median low-income energy bill by 25% from $1,464 to $1,098. Using the median low-income household income of $18,000, this equates to a reduced energy burden of 6.1%. Reducing the median low-income energy burden from 8.1% to 6.1% is a 25% reduction. Following this same methodology, our 2016 metro energy burden report estimates a 30% reduction based on the 2011 and 2013 AHS data.

Strategies to Accelerate, Improve, and Better Target Low-Income Housing Retrofits, Energy Efficiency, and Weatherization

Many local and state governments, utilities, and community-based organizations have already begun to identify energy efficiency as a key strategy for lowering high energy burdens. To date, we have identified nine cities (Atlanta, Cincinnati, Houston, Minneapolis, New Orleans, Oakland, Philadelphia, Pittsburgh, Saint Paul) and six states (Colorado, New Jersey, New York, Oregon, Pennsylvania, Washington) that have set energy-burden-focused policies, goals, or programs with energy efficiency as a key component (see **Appendix C**). For example, the State of Oregon's *Ten-Year Plan to Reduce the Energy Burden in Oregon Affordable Housing* states that its goal is to "reduce the energy burden on the low-income population in Oregon, while prioritizing energy efficiency to achieve that reduction" (OR DOE, OR PUC, and OHCS 2019). At the city level, Philadelphia's Clean Energy Vision Plan set a goal to eliminate the energy burden for 33% of Philadelphians. To accomplish this, the city has designed and funded multiple pilot programs to reduce high energy use in multifamily and single-family buildings. See **Appendix C** for more information on energy-burden-focused city- and state-led actions.

FIGURE 7. Key strategies to lower high energy burdens by better targeting low-income energy efficiency programs, ramping up investment, and improving program design and best practices

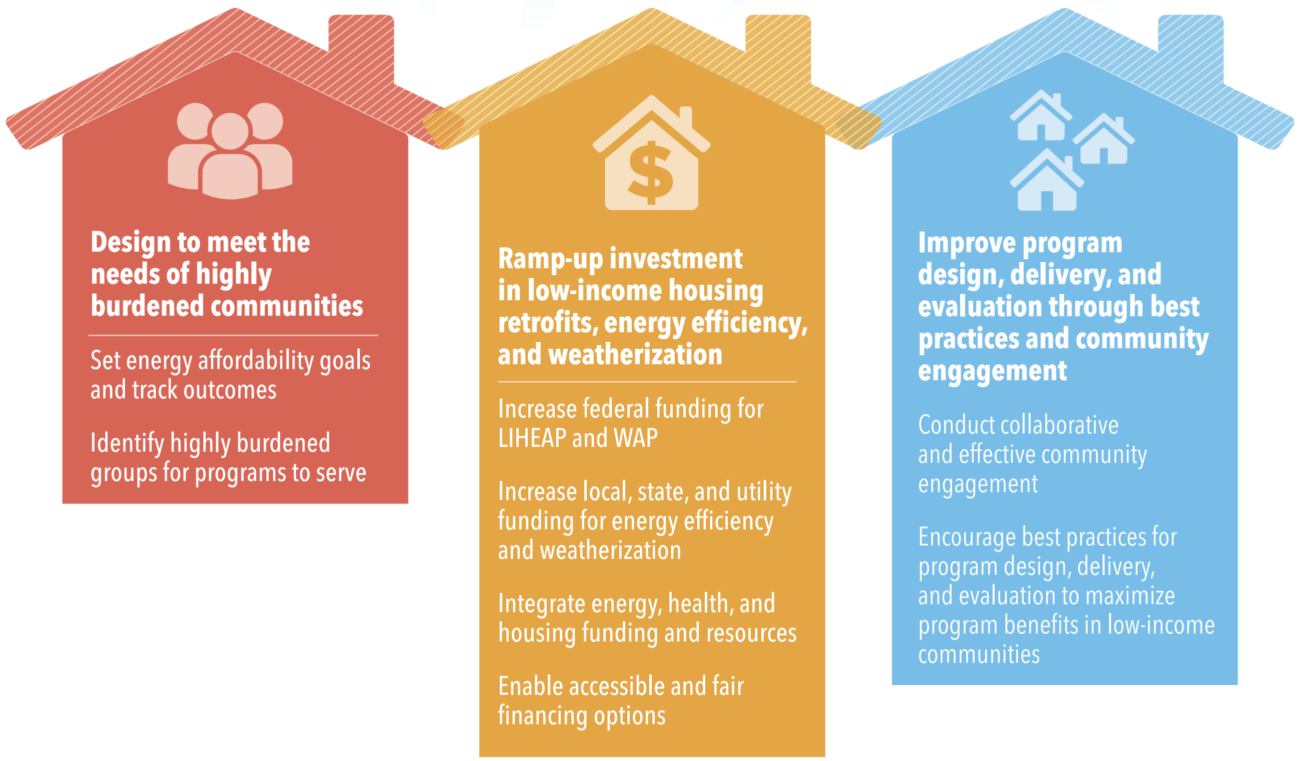


Figure 7 illustrates the key strategies to design programs to meet the needs of highly burdened communities, increase funding, and improve program design to have the greatest impact.

Design to Meet the Needs of Highly Burdened Communities

Focusing low-income energy efficiency and weatherization investment on residents with the highest burdens can greatly alleviate energy insecurity. Local and state governments and utilities can conduct more granular and detailed energy insecurity studies or analyses to help identify which local communities have the highest burdens. They can also use other energy equity and justice-related metrics and indicators to target resources to and investment in these communities. One tool for doing this analysis is the U.S. Department of Energy (DOE) Low Income Energy Affordability Data (LEAD) tool (see text box 1). Policymakers and program implementers can use a community-based approach to develop programs to invest in communities with high burdens. Cities and states can also set energy affordability goals and policies, and then track outcomes to ensure that the communities most impacted by energy insecurity receive the benefits of energy efficiency investments.

TEXT BOX 1. ENERGY BURDEN ASSESSMENTS: LOW INCOME ENERGY AFFORDABILITY DATA (LEAD) TOOL

The Department of Energy's Low Income Energy Affordability Data Tool (LEAD), developed with the National Renewable Energy Laboratory, aims to help states, communities, and other stakeholders create better energy strategies and programs by improving their understanding of low-income housing and community energy characteristics. LEAD is a web-accessible interactive platform that allows users to build their own state, county, and census tract and city profiles with specific household energy characteristics associated with various income levels and housing type, vintage, and tenure. The tool provides three principal metrics—energy burden, annual average housing energy costs, and housing counts—along with map and chart-based visualizations (Ma et al. 2019). States and local governments have begun using the LEAD tool in planning. For example, New Jersey cited its use of LEAD in the development of its new Office of Clean Energy Equity (New Jersey Legislature 2020).

LEAD is available for free at energy.gov/eere/slsc/maps/lead-tool.

SET ENERGY AFFORDABILITY GOALS AND TRACK OUTCOMES

State and local policymakers can set energy affordability and energy burden goals as a first step to addressing energy insecurity in their communities. Examples of such goals include reducing energy burdens by certain percentages, lowering energy burdens for all households to a certain threshold, or targeting resources toward individuals with high energy burdens. By focusing on the needs of those who are disproportionally burdened—particularly at the intersection of criteria such as income, race and ethnicity, and age—policymakers can set policies and create programs that have the greatest impact on addressing energy insecurity. Table 4 lists cities that have established energy burden and affordability goals. **Appendix C** includes additional city and state energy burden policies.

To establish energy burden goals, cities, states, and utilities can conduct baseline studies to understand the state of energy burdens, poverty, housing, and access to energy efficiency investments in their communities. They can then establish an appropriate goal and strategies to accomplish that goal.

Coordinating goal setting with other state and local priorities can help cities to streamline their efforts. Some cities—such as Minneapolis and New Orleans—include energy burden goals in their climate action plans as a strategy to reduce greenhouse gas emissions and achieve more equitable outcomes. States such as New York have also used energy burdens in statewide energy affordability policy plans.

Energy burden maps and visualizations are a useful tool for cities and states to achieve more equitable and affordable energy in their communities, move resources toward overburdened communities, and address other climate and equity goals. The DOE's LEAD tool provides one way to create energy burden visualizations. Plans should include specific strategies for lowering high energy burdens, as well as methods and strategies to track iterative progress.

In addition to goals, some cities have begun using energy burden as an equity indicator metric. For example, the city of Oakland includes energy cost burden as a metric in its *2018 Equity Indicators* report (City of Oakland 2018) to measure equity within essential housing services. The city found that energy burdens were higher for Black, Hispanic, and Asian households in the city as compared to white households. Similarly, the Minneapolis Climate Action Plan indicates that reporting on plan progress should also include equity indicators to measure whether energy burden reductions are equitable (City of Minneapolis 2013). Text box 2 offers examples of how governors and policymakers in four states—Pennsylvania, New York, Oregon, and Washington—created goals and policies around energy burdens to address energy insecurity in their states. To date, energy burden goals are largely set and acted upon by climate and energy officials at the city and state level. Such metrics and goals are rarely part of larger

TABLE 4. Cities with energy burden goals and strategies

City	Description	Data source
Atlanta	The Resilience Strategy includes action to lift energy burden on 10% of Atlanta households.	City of Atlanta 2017
Cincinnati	The Green Cincinnati Plan set a goal to reduce household energy burdened by 10% compared to current levels.	City of Cincinnati 2018
Houston	The Climate Action Plan includes a goal to promote weatherization programs to reduce residential energy consumption and focus on reducing energy burdens of low-income populations.	City of Houston 2020
Minneapolis	The Climate Action Plan states that the city will prioritize neighborhoods with high energy burdens for strategy implementation.	City of Minneapolis 2013
New Orleans	The Climate Action Plan includes two strategies to reduce the high energy burdens of the city's residents.	City of New Orleans 2017
Philadelphia	The Clean Energy Vision Plan set a goal to eliminate the energy burden for 33% of Philadelphians.	City of Philadelphia 2018
Saint Paul	The city set a 10-year goal to reduce resident energy burden so that no household will spend more than 4% of its income on energy bills.	City of Saint Paul 2017

TEXT BOX 2. CASE STUDIES: STATE-LED ENERGY AFFORDABILITY EFFORTS

New York Energy Affordability Goal. In 2016, Governor Andrew M. Cuomo became one of the first U.S. government officials to issue a policy aimed at addressing high energy burdens. Through the state's first ever Energy Affordability policy, he aims to ensure that no New Yorker spends more than 6% of their household income on energy (New York 2016). New York continues to explore pathways to reducing energy burden to 6% for all New Yorkers through a combination of enhanced bill assistance, energy efficiency, and increased coordination among state agencies responsible for energy, bill assistance, and affordable housing.

Oregon's Strategies to Achieve Affordability. Issued by Governor Kate Brown in 2017, Executive Order 17-20 targets state agencies to improve energy efficiency. Section 5(b) emphasizes a prioritization of energy efficiency in affordable housing to reduce utility bills (Oregon 2017). In response to this directive, the Oregon Housing and Community Service Department partnered with the DOE and the Public Utility Commission to develop an assessment to identify the energy burden of Oregon's low-income population and also prioritize energy efficiency. The interagency assessment concluded that energy costs for low-income Oregonians are nearly $350 million per year, and it identified more than $113 million annual potential energy cost savings that can be achieved through low-income energy efficiency programs across the state (OR DOE, OR PUC, and OHCS 2019). The order identifies a number of strategies to achieve these cost savings, such as adopting energy codes for new buildings and including retrofit measures, such as smart thermostats and replacing electric resistance heating.

Pennsylvania Energy Affordability Study. In 2019, the Pennsylvania Public Utility Commission (PA PUC) released a report that examined home energy affordability for the state's low-income customers (Pennsylvania PUC 2019a). The report's goal was to determine what constitutes an affordable energy burden for low-income households in the state, which would advise changes to the bill payment assistance programs to achieve these affordable energy burden levels. In 2020, the PA PUC set a new policy to direct the state's regulated utilities to ensure that low-income customers spend no more than 10% of their income on energy bills and that the lowest-income customers spend no more than 6% of their income on energy bills (Pennsylvania PUC 2019b).

Washington Clean Energy Transformation Act. In 2019, Governor Jay Inslee passed the Clean Energy Transformation Act (CETA), which sets specific goals to achieve 100% clean electricity across Washington by 2045. Under CETA, the Washington Department of Commerce will assess the energy burdens of low-income households and the energy assistance offered by electric utilities. The department will consult with local advocates of vulnerable populations and low-income households to improve energy assistance programs. The department will publish a statewide summary to include the estimated level of energy burden and energy assistance among electric customers, identify drivers of energy burden and energy efficiency potential, and assess the effectiveness of current utility programs and mechanisms to reduce energy burdens (Washington State Department of Commerce 2020).

public health strategies and priorities despite their wide-reaching health implications.

IDENTIFY HIGHLY BURDENED GROUPS FOR PROGRAMS TO SERVE

Overburdened households, especially Black, Native American, Hispanic, and other communities of color, often are either marginalized and overlooked by utilities' energy efficiency program marketing or face additional barriers to program participation, such as high cost or financing barriers (Leventis, Kramer, and Schwartz 2017). Creating targeted energy efficiency marketing beyond direct billing mailers can drive positive outcomes for the whole system.

Policymakers can also look beyond energy burden as an indicator to identify highly burdened groups, taking into account factors such as income, unemployment rates, race and ethnicity, geography, education, and multiple other stressors—including air pollution and health indicators. By using metrics beyond energy burden, policymakers and program implementers can better invest resources in communities that experience the highest levels of marginalization underinvestment, and negative social and health impacts (Lin et al. 2019). Policymakers can design and implement programs that meet the needs of highly burdened groups through robust community engagement. For example, local governments can design programs to improve access to affordable, energy-efficient housing by mandating or incentivizing stringent energy efficiency standards, streamlining permit and inspection processes, and amending zoning codes for construction of more housing units, while also using neighborhood approaches to involve and empower community members in these processes (Samarripas and de Campos Lopes 2020).

TEXT BOX 3. MEETING THE NEEDS OF HIGHLY BURDENED GROUPS: CASE STUDIES

Minneapolis Green Zones: The Minneapolis Climate Action Plan's Environmental Justice Working Group developed the idea of *Green Zones*, a place-based policy initiative aimed at improving health and supporting economic development. The city used data to identify two such zones—a Northern Green Zone and a Southern Green Zone—where residents face disproportionate burdens across areas such as equity, displacement, air quality, brownfields and soil contamination, housing, green jobs, food access, and greening (City of Minneapolis 2020). Once created, the city designed programs to direct investment into these communities. The Green Zones provide an example of how policymakers can work to identify highly burdened communities and create programs that meet the needs of residents in these areas.

Energy Burden as a Program Qualification: Efficiency Vermont. Efficiency Vermont (EVT), the energy efficiency program implementer for the state's utility-funded energy efficiency programs, conducted a 2018 study of equity measurements to better understand how the clean energy industry defines, collects, analyzes, and reports data on equity. This study informed changes to the design of EVT's Targeted High Use Program, which launched in 2011 and originally qualified customers based on two factors: income (< 80% of Area Median Income [AMI]) and a minimum energy use of 10,000 kWh/year. The program historically served approximately 350 households per year, working with the DOE's Weatherization Assistance Program (WAP) to conduct energy assessments and then install LEDs and water-saving measures, identify appliances for replacement, and replace high-efficiency heat pumps and heat pump water heaters where appropriate. Through its equity analysis, EVT determined that the energy use threshold was too high and excluded many customers with high energy burdens—but lower energy use—from accessing the program. In 2019, EVT changed the program qualification to two factors: income (< 80% AMI) and electric energy burden (≥ 3%). This change allowed it to recenter the program around energy burden reduction by qualifying not only more customers but also those who have high energy burdens yet may have previously been disqualified based on their energy use.

Efforts to alleviate high energy burdens should aim not only to identify those with high burdens and energy use but also to understand who has been overlooked by past efforts and develop strategies to address the needs of these households. Text box 3 contains additional case studies of city- and utility-led strategies to meet the needs of their overburdened communities.

Accelerate Investment in Low-Income Housing Retrofits, Energy Efficiency, and Weatherization

The current need for low-income energy efficiency and weatherization far exceeds allocated resources. In 2017, utility-led energy efficiency administrators allocated only 5% of electric and 22% of natural gas energy efficiency expenditures to low-income programs (CEE 2019). This funding allocation shows that energy efficiency funds are not currently distributed to ensure that low-income households have equitable access to these investments and their benefits.

Policymakers and advocates can work toward leveraging and allocating additional funding for low-income energy efficiency and weatherization programs. They can also help ensure that these programs follow best practices to increase their impact. Following are several useful strategies for ramping up additional funding for low-income energy efficiency and weatherization.

INCREASE FEDERAL FUNDING FOR LIHEAP AND WAP

Although an estimated 36 million U.S. households are currently eligible for weatherization, the DOE's Weatherization Assistance Program (WAP) has served only 7 million households over the past 40 years (Bullen 2018; DOE 2016). WAP serves about 100,000 homes per year through DOE and leveraged funds, which is far fewer than both the eligible households nationally and the 15.7 million severely energy burdened households estimated in this study (NASCSP 2020b). At the current rate, it would take 360 years to weatherize all eligible households through WAP—assuming no more households become WAP-eligible over time.

Congress funds WAP and allows funds to be transferred to the program from the Department of Health and Human Services' Low-Income Home Energy Assistance Program (LIHEAP). WAP can also utilize additional leveraged funds. States can transfer 15% (or up to 25% with a waiver) of LIHEAP bill assistance funds to WAP to supplement DOE weatherization funding. Over the past 10 years, annual expenditures directed toward weatherization have ranged from $1 billion to $3 billion per year, with the American Recovery and Reinvestment Act greatly increasing low-income funding for WAP (Brown et al. 2019). The National Association for State Community Services Programs' 2018 funding report estimates that WAP grantees had access to $1.1 billion in total available funding in 2018, with $247 million direct base funding from the DOE, $453 million from LIHEAP-transferred funding, and $408 million from utilities, state-sourced revenue, and other sources (NASCSP 2020b). Non-DOE WAP funds in 2018 added an additional $861 million, or $3.48 for every DOE-invested dollar (NASCSP 2020b).

The federal government has the ability to increase both WAP and LIHEAP budgets to better meet households' needs. From 2008 to 2018, DOE base funding for WAP has fluctuated from a high of $450 million in 2009 to a low of $68 million in 2012 (DOE 2009, 2012). In 2020, Congress allocated $305 million to WAP—a 23% increase ($58 million) compared to the funds allocated in 2018 (DOE 2020). Even so, leveraging additional state, local, and other funding helps supplement and increase available weatherization funds. In addition, states can decide to increase the LIHEAP percentage they transfer to WAP to better support the program. Further, it is essential that the increased demand for adequate cooling systems be assessed in the allocation of WAP and LIHEAP funds. For households across the South, rising temperatures and the increasing frequency and duration of heat waves are likely to increase cooling needs—and thus energy expenses (Berardelli 2019).

The COVID-19 pandemic has added to the urgency of increasing support for low-income bill payment assistance. On May 8, 2020, the federal government authorized $900 million in supplemental LIHEAP funding to help "prevent, prepare for, or respond to" home energy needs surrounding the national emergency created by COVID-19 (HHS 2020). On May 15, 2020, the U.S. House of Representatives passed the Health and Economic Recovery Omnibus Emergency Solutions (HEROES) Act, which would add an additional $1.5 billion for LIHEAP to address energy access and security issues resulting from the COVID-19 pandemic (116th Congress 2020). As of publication, the Senate has not passed this legislation.

INCREASE STATE, LOCAL, AND UTILITY FUNDING FOR ENERGY EFFICIENCY AND WEATHERIZATION

Funding from states, local governments, and utilities can also support low-income energy efficiency and weatherization efforts. In many states, PUCs can set low-income energy efficiency spending and/or savings requirements—as well as energy burden reduction targets—for their regulated utilities. As of 2017, of the 27 states with electric and/or natural gas Energy Efficiency Resource Standards (EERS), 18 had low-income energy efficiency spending requirements in place (Berg and Drehobl 2018; Gilleo 2019). States and local governments can also fund and implement their own energy efficiency and weatherization programs separately from WAP or as a WAP add-on. They can, for example, allocate funds—such as from Community Development Block Grants (CDGB)—to joint or independent energy efficiency and weatherization programs.

Policy approaches can be aligned to leverage funding resources and maximize benefits for residents, including reduced energy burdens and safer and healthier housing.

Appendix C and text box 4 include examples of cities and states that created independent energy efficiency and weatherization programs to address high energy burdens.

INTEGRATE ENERGY, HEALTH, AND HOUSING FUNDING AND RESOURCES.

High energy burdens, housing, and health are inextricably linked. In our study, many of the groups who experience high energy burdens also live in inadequate housing and disproportionally suffer from a variety of other harms, including higher than average exposures to environmental pollution (Tessum et al. 2019) and higher than average rates of certain preventable illnesses and diseases (CDC 2013). Although the recent COVID-19 pandemic has sharply illustrated this disparity, the same story plays out across a variety of preventable harms.[19] Policy approaches can be aligned to leverage funding resources and maximize benefits for residents, including reduced energy burdens and safer and healthier housing.

The benefits of these programs can be much greater when the goals of saving energy and protecting health are sought in tandem. Typical energy efficiency and weatherization services can provide a range of health benefits. Poorly sealed building envelopes allow pests, moisture, and air pollution to infiltrate (Institute of Medicine 2011), which can harm respiratory health through pest allergies, mold growth, and lung disease. Leaky windows, faulty HVAC systems, and poor insulation can lead to cold drafts and extreme home temperatures during summer and winter months. This can trigger heat-related illnesses and asthma attacks, as well as exacerbate other respiratory illnesses (AAFA 2017; American Lung Association 2020; CDC 2016). Addressing these issues through energy efficiency and weatherization will result in improved health outcomes; it will also reduce household energy burdens.

[19] For more on the disparities among COVID-19 fatalities, see Malcolm and Sawani (2020); Hooper, Nápoles, and Pérez-Stable (2020); and CDC (2020).

TEXT BOX 4. CITY- AND STATE-FUNDED ENERGY AFFORDABILITY PILOT PROGRAMS

Philadelphia: To meet its energy burden goals, Philadelphia has partnered on multiple pilot programs to reduce high energy burdens for low-income single and multifamily households. In 2017, the Philadelphia Energy Authority (PEA) launched its Multifamily Affordable Housing Pilot program in partnership with public and private-sector groups, including the local electric and natural gas utilities, property owners, energy service companies, program implementers, contractors, and technology providers (PEA 2020a). The program's goal was to deliver deep energy savings of more than 30% to low-income multifamily building residents in the city. In 2018, PEA and partners completed the program's first phase, which included low-cost measures and measures to collect energy data. These data were then used in the second phase to design deeper savings measures, such as HVAC and building envelope measures.

In response to COVID-19, PEA is developing a platform with its partners and advocates to coordinate and streamline low-income homeowner services aimed at improving home safety, health, affordability, and comfort (PEA 2020b). Set to launch in 2021, PEA's Built to Last pilot program aims to deliver comprehensive home improvements that will reduce energy burden while improving health and safety. The program will serve 80–100 homes and will streamline benefit screening, property assessment, and construction management. To cover program costs, Built to Last aims to combine available funding with grants and microfinancing options. PEA plans to deploy the Built to Last program at a larger scale in 2022 (PEA 2020b).

Pittsburgh. The city recognized that while Pittsburgh residents have some of the lowest utility rates in the country, they still pay almost twice the national average for their energy bills, leading to high energy burdens. Over the course of a few years, Pittsburgh developed a Climate Action Plan and launched both its resilience strategy (OnePGH) and its equality indicator project. These three projects helped the city identify residential energy burden as one of the primary challenges that local communities face (City of Pittsburgh 2019). As part of the Bloomberg Mayor's Challenge, Pittsburgh created Switch PGH to address high energy burdens through a civic engagement tool that gamifies home improvement (Mayors Challenge 2018). Switch PGH helps residents make lasting energy efficiency behavior changes and incentivizes home upgrades to reduce energy burdens.

Colorado. The Colorado State Energy Office awarded GRID Alternatives, a solar installer that focuses on the low-income market, a $1.2 million grant to launch a demonstration project with the goal of reducing the energy burden for more than 300 low-income households. The program also aimed to improve understanding of how to make community solar programs with low-income participants mutually beneficial for both utilities and participants (Cook and Shah 2018) Through this program, households saved from 15% to more than 50% on their utility bills, with an average annual savings of $382.

Myriad programs exist to address health and safety issues within homes, as well as to preserve and grow the affordable housing stock. Opportunities exist to integrate these programs and resources to more comprehensively address the energy, health, and housing needs of the households most in need of assistance.[20] For example, many homes must defer energy efficiency investments due to a home's physical issues, such as those related to structural deficiencies, moisture, and/or mold. According to Rose et al. (2015), WAP agencies estimated that such issues led to a 1–5% deferral rate for WAP income-eligible homes. In some areas, however, the problem is worse. In western Wisconsin, for example, a Community Action Agency and WAP provider serving four counties reported a deferral rate approaching 60% (NASCSP 2020a). Addressing nonenergy-related housing issues would allow more homes to be weatherization-ready.

Integrating programs creates opportunities to streamline administration and reduce operating redundancies that can leave more funding for energy efficiency and weatherization measures that enable households to save on energy costs. Pooling resources and establishing cross-sector referral networks not only stretches program budgets, but it also can make programs more accessible for residents by streamlining eligibility and enrollment processes. For instance, offering a single contact point or a streamlined process can give participants a variety of services simultaneously to meet their energy, health, and housing needs (Levin, Curry, and Capps 2019). This can help mitigate barriers that arise when people have to navigate multiple separate services with varying eligibility requirements and enrollment processes. Efficiency Vermont's Healthy Homes Initiative (HHI) is one such example. A partnership between the state's WAP partners and community-based organizations that offer health interventions, HHI is coordinated through Vermont's Office of Economic Opportunity. Using

[20] ACEEE recently published several reports exploring the intersection of health and energy, including *Protecting the Health of Vulnerable Populations with In-Home Energy Efficiency: A Survey of Methods for Demonstrating Health Outcomes* (www.aceee.org/research-report/h1901); *Making Health Count: Monetizing the Health Benefits of In-Home Services Delivered by Energy Efficiency Programs* (www.aceee.org/research-report/h2001); and *Braiding Energy and Health Funding for In-Home Programs: Federal Funding Opportunities* (www.aceee.org/research-report/h2002).

One Touch, an electronic platform for healthy home resources, HHI has established a robust referral network and successfully integrated healthy home principles into its residential energy efficiency program design.

The health sector is also beginning to realize the efficiencies of combining health and energy assessments and interventions (Hayes and Gerbode 2020). For example, a single contractor could be trained to both identify and address a family's asthma triggers, energy efficiency needs, and fall risks, thereby reducing the associated logistical burden on residents who might otherwise have to coordinate each service individually. Efforts such as this are beginning to appear across the country. In 2015, the state of Washington directed more than $4 million in competitive grants to fund collaborations among clinical practitioners, home retrofitters, and community service organizations as a means of empowering clinicians and others to refer participants for a range of coordinated services (e.g., comprehensive in-home repairs and community health worker visits) (Levin, Curry, and Capps 2019). In New York, the State Energy Research and Development Authority (NYSERDA) recently kicked off a value-based payment pilot program that seeks to implement a healthy homes approach; through this program, Medicaid managed care organizations will partly cover residential upgrades when healthcare cost savings and benefits to residents are verified (NYSERDA 2018). Such cross-sectoral approaches to energy efficiency and weatherization seek to address some of the major root causes of health and energy inequities while making enrollment and participation feasible and accessible for residents. The benefits of energy efficiency cut across the health and energy sectors; by working to integrate resources, policymakers can maximize these benefits.

Housing policy can also help ensure that energy efficiency is integrated into efforts to upgrade and expand the affordable housing stock. State and local governments can play a key role in these integrating approaches. For example, a growing number of state housing finance agencies (HFAs)—state-chartered entities responsible for ensuring affordable housing across states—have included energy efficiency requirements in their allocation criteria for low-cost financing programs such as federal Low-Income Housing Tax Credits and grant programs administered to local governments. The same is true for local housing authorities, which increasingly incorporate energy efficiency into the maintenance and repair of their subsidized housing stock (EPA 2018). Text box 5 offers a brief case study of how one local government systematically required energy efficiency in its rental certification process, ensuring that all types of rental housing meet a specific level of energy performance.

ENABLE ACCESSIBLE AND FAIR FINANCING OPTIONS

Many low-income households face barriers—such as credit eligibility—to investing in energy efficiency; these barriers can prevent them from participating in energy efficiency programs or installing energy efficiency upgrades that require financing for up-front costs. With the right consumer protections in place, financing can enable households to undertake cost-effective energy efficiency investments to lower their energy usage and bills. Local and state governments, utilities, private lenders, and nonprofit or community-based organizations can act to create and/or enable low- or no-cost financing options (i.e., payments are offset by energy cost savings) for energy efficiency investments.

Several types of financing instruments, such as on-bill payment (i.e., loan repayments included on the utility bill) and energy service agreements are becoming more common (Leventis, Kramer, and Schwartz 2017). Similarly, opportunities such as Commercial Property Assessed Clean Energy (C-PACE) can increase energy efficiency financing in the affordable multifamily sector. SEE Action's 2017 report, *Energy Efficiency Financing for Low- and Moderate-Income Households,* provides a comprehensive overview of the pros and cons of various financing options for both single and multifamily low-income households (Leventis, Kramer, and Schwartz 2017).

Improve program design, delivery, and evaluation through best practices and community engagement

Program designers and implementers can collaborate and effectively engage with a community to create programs that fit its specific needs rather trying to fit the community into an existing program design. They can also incorporate best practices into their program design, delivery, and evaluation, and can emulate successful peer program models to increase program effectiveness and impact.

CONDUCT COLLABORATIVE AND EFFECTIVE COMMUNITY ENGAGEMENT

To create programs that effectively reduce high energy burdens, energy efficiency and renewable energy program designers and implementers can work to engage and include local stakeholders throughout the program planning and implementation processes.

By connecting with, listening to, and partnering with community-serving organizations and community members in highly impacted communities, program

TEXT BOX 5. THE CITY OF BOULDER'S SMARTREGS PROGRAM

In 2010, the city council in Boulder, Colorado, adopted SmartRegs, a program that requires all rental housing units in the city to demonstrate that their efficiency approximates or exceeds the standards set by the 1999 Energy Code. The program was integrated into the city's existing rental license program, which requires a rental property to obtain and renew its rental license every four years. This renewal entails an inspection for health and safety measures, and SmartRegs added energy efficiency requirements that must be met to certify that the property is approved for rental. All single- and multifamily units that offer long-term licensed rental housing are subject to the requirement. For larger multifamily buildings, a sample of representative apartments can be inspected.

Boulder also offers a companion EnergySmart program that provides technical assistance, help with selecting contractors for energy efficiency improvements, and financial incentives beyond those offered by the local utility. EnergySmart is funded primarily by Boulder County and provides services to all municipalities in the county.

SmartRegs has been recognized not only for saving energy and related costs but also for leading to widescale upgrades in the city's rental housing stock. Over the course of the eight-year compliance timeline, nearly all of the approximately 23,000 licensed rental units have become compliant (City of Boulder 2020a). The most common upgrades were attic, crawlspace, and wall insulation. The average upgrade cost has been about $3,000 per unit, of which an average of $579 was paid by city- and utility-sponsored rebates. As of 2018, the city estimates that the program has saved about 1.9 million kWh of electricity, 460,000 therms of natural gas, $520,000 in energy costs, and 3,900 million metric tons of carbon dioxide. The city estimates the total investment in the program at just over $8 million, including nearly $1 million in rebates (City of Boulder 2020b).

administrators can identify the best measures, financing options, delivery methods, and marketing strategies to help residents reduce high energy burdens and meet their needs. Achieving this connection requires partnering with the community on program design and identifying and addressing barriers to participation for key stakeholders. This often requires engagement and trust-building over a long time period.

Robust community engagement incorporates the voices of and/or delegates power to community members. Such engagement can help develop neighborhood-centered programs that are most successful when combined with consistent funding, quality delivery infrastructure, and targeted outreach and engagement (USDN 2019). For more information on best practices in stakeholder engagement, see the DOE's Clean Energy for Low-Income Communities (CELICA) Online Toolkit at betterbuildingssolutioncenter.energy.gov/CELICA-Toolkit/stakeholder-engagement.

To include residents with high energy burdens in policy and program design, cities, states, and utilities can establish working groups, task forces, committees, and other structures that give residents a formal decision-making role. Creating this engagement when energy insecurity strategies, goals, and/or programs are first being developed allows for more input and direction from community members. Local energy planning efforts can also start with a community needs assessment led by a formal body of community residents. Local government and community leaders can then use this assessment's findings to drive local energy affordability policies and program developments based on the findings' prioritized needs and strategies.

Policymakers and program implementers can minimize stakeholder and community participation barriers by funding or compensating participants for their time and participation in stakeholder engagement processes. For example, offering stipends to compensate participants for their time and expertise, setting realistic time expectations, creating accessible logistics, and offering additional incentives can increase participation and access (Curti, Andersen, and Write 2018). Other incentives to reduce engagement barriers include childcare, meals, and transit passes.

Policymakers can also move to a model of *energy democracy* in which community residents are innovators, planners, and decision makers on how to use and create energy in a way that is local, renewable, affordable, and just (Fairchild and Weinrub 2017). Communities that have transitioned to an energy democracy have shifted away from "an extractive economy, energy, and governance system to one that is regenerative, provides reparations, transforms power structures, and creates new governance and ownership practices (ECC 2019)." The Emerald Cities Collaborative led the creation of an *Energy Democracy Scorecard*, which provides a framework for communities to move toward an energy democracy. Policymakers can work to create energy democracy frameworks in their communities by working with community members to recognize power imbalances and create dialogues about systemic barriers that must be addressed in order to correct long-standing injustices and inequalities in the energy and related sectors. This can help move the energy planning model to one of community self-determination and shared ownership. For more information, see emeraldcities.org/about/energy-democracy-scorecard.

ENCOURAGE BEST PRACTICES FOR PROGRAM DESIGN, DELIVERY, AND EVALUATION TO MAXIMIZE BENEFITS IN LOW-INCOME COMMUNITIES

Researchers from ACEEE and other organizations have established numerous best practice strategies and case studies of ways to improve and expand low-income energy efficiency programs and investments (Aznar et al. 2019; Nowak, Kushler, and Witte 2019; EDF 2018; Gilleo, Nowak, and Drehobl 2017; Samarripas and York 2019; Cluett, Amann, and Ou 2016; Ross, Jarrett, and York 2016; Reames 2016).

Table 5 includes low-income program best practices across five categories: coordination, collaboration, and segmentation; funding and financing; measures, messaging, and targeting; evaluation and quality control; and renewables and workforce development. **Appendix D** offers more detailed descriptions and examples of each of these best practices.

TABLE 5. Low-income program best practices by category

Coordination, collaboration, and segmentation	Funding and financing	Measures, messaging, and targeting	Evaluation and quality control	Renewables and workforce development
Community engagement and participatory planning	Leverage diverse funding sources	Include health and safety measures and healthier building materials	Collect and share metrics	Integrate energy efficiency and solar
Statewide coordination models	Inclusive financing models	Prioritize deep energy-saving measures	Conduct robust research and evaluation	Support the development of a diverse and strong energy efficiency workforce
One-stop-shop program models	Align utility and housing finance programs	Integrate direct-installation and rebate programs	Include quality control	
Market segmentation		Target high energy users and vulnerable households	Incorporate nonenergy benefits	
Fuel neutral programs		Incorporate new and emerging technologies in low-income programs		
		Effectively message programs in ways that provide clear value and actionable guidance		

Conclusions and Further Research

High energy burdens and energy insecurity are well-documented and pervasive national issues. Even in 2017, a time of economic prosperity, well over one-quarter of all U.S. households experienced a high energy burden. As this indicates, we need a renewed focus on equitable clean energy development and just energy transitions to ensure that investments in energy efficiency and renewable energy address energy insecurity. Climate change also underscores the urgency in addressing high household energy burdens. As temperatures continue to rise and heat waves become more common, access to clean, affordable energy is needed more than ever. We need cross-sectoral approaches that address the intersection of energy, health, and housing in the face of climate change.

Both nationally and in metro areas, this study finds that certain groups pay disproportionally more of their income on energy costs, including low-income households, communities of color, older adults, renters, and those residing in older buildings. Even though each metro area has a unique energy burden landscape, all cities have energy security inequities and can work to address them through collaborative policy and program decisions. Policymakers at the local, state, and utility levels can direct energy efficiency and renewable energy investments to disadvantaged and historically underinvested communities. They can then measure and ensure that these investments provide equitable benefits to local jobs, community health, and residential energy affordability.

Energy burdens are not the sole indicator of energy insecure households but rather provide one metric for determining energy insecurity. Further research is needed to identify the main physical drivers of high energy burdens, as well as the policies best suited to address the needs of the most highly energy burdened households. To better understand their communities' energy insecurity landscape, cities and states—and their energy, health, and housing agencies—as well as utilities are well-positioned to conduct detailed energy burden analyses, including qualitative data collection and interviews. Such studies would enable a first step toward setting more targeted energy affordability and energy burden goals and creating equitable, cross-sectoral policies and programs for achieving greater access to affordable energy for all.

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APPENDIX A.
Energy Burden Data

Appendix A.1—National Energy Burden Data

A1. National energy burden data including sample sizes, median energy burdens, median income, median monthly energy bills, and the percentage of households in each group with a high and severe burden

Subgroups	Sample size	Median energy burden	Median annual income	Median annual energy expenditures	High burden percentage (>6%)	Severe burden percentage (>10%)
All households	53,539	3.1%	$58,000	$1,800	25%	13%
Low-income (≤ 200% FPL)	16,685	8.1%	$18,000	$1,464	67%	40%
Low-income with adult over 65	6,018	9.3%	$15,000	$1,440	74%	47%
Low-income with child under six	2,665	7.1%	$26,400	$1,800	59%	33%
Low-income with disability	5,759	8.7%	$14,660	$1,344	69%	43%
Non-low-income (> 200% FPL)	36,854	2.3%	$84,005	$2,040	6%	1%
White (non-Hispanic)	33,219	2.9%	$65,000	$1,920	23%	11%
Black	7,747	4.2%	$36,000	$1,560	36%	21%
Hispanic	8,435	3.5%	$47,400	$1,680	28%	14%
Native American	1,003	4.2%	$40,000	$1,680	36%	19%
Older adults (65+ years)	15,750	4.2%	$40,015	$1,800	36%	19%
Renters	20,455	3.4%	$36,000	$1,320	30%	17%
Owners	33,082	3.0%	$75,000	$2,160	22%	11%
Single family	37,423	3.1%	$70,020	$2,160	24%	12%
Multifamily (5+ units)	9,936	2.4%	$35,450	$960	22%	12%
Low-income multifamily (5 + units, ≤ 200% FPL)	4,563	5.6%	$14,300	$960	47%	26%
Small multifamily (2–4 units)	3,708	3.4%	$34,700	$1,200	29%	17%
Manufactured homes	2,440	5.3%	$34,800	$1,800	45%	25%
Buildings built before 1980	28,013	3.4%	$50,040	$1,800	29%	15%
Buildings built after 1980	25,525	2.8%	$66,000	$1,920	21%	11%

Appendix A.2—Regional Energy Burden Data

A2.1. Regional energy burdens, including sample sizes for each region, median energy burdens, median monthly energy bill, and the percentage with high and severe burdens

Region	Sample size	Median energy burden	Median annual income	Median annual energy expenditures	Upper-quartile energy burden	High burden percentage (>6%)	Severe burden percentage (>10%)
East North Central	7,422	3.6%	$52,500	$1,920	6.8%	29%	15%
East South Central	2,177	4.4%	$39,400	$1,800	8.5%	38%	21%
Middle Atlantic	4,851	3.4%	$60,000	$2,040	6.8%	29%	16%
Mountain	3,932	2.9%	$57,625	$1,680	5.2%	21%	11%
New England	2,778	3.5%	$71,985	$2,640	6.7%	29%	15%
Pacific	11,177	2.3%	$69,800	$1,680	4.5%	18%	9%
South Atlantic	11,363	3.2%	$56,120	$1,920	6.2%	26%	14%
West North Central	2,412	3.1%	$55,100	$1,800	5.8%	25%	12%
West South Central	7,427	3.3%	$52,000	$1,800	6.0%	25%	13%
National	53,539	3.1%	$58,000	$1,800	6.0%	25%	13%

A2.2. Regional median energy burdens for income-based groups

Region	Low-income (≤200% FPL)	Low-income with older adults (65+)	Low-income with child under 6	Low-income with disability	Low-income multifamily (5+ units, ≤200% FPL)	Non-low-income (>200% FPL)
East North Central	9.1%	9.8%	8.2%	9.2%	6.0%	2.6%
East South Central	9.1%	10.0%	8.6%	9.9%	6.6%	2.9%
Middle Atlantic	9.4%	10.7%	7.9%	10.2%	6.9%	2.6%
Mountain	6.9%	8.4%	5.7%	7.7%	4.5%	2.2%
New England	10.5%	11.6%	9.6%	10.8%	5.6%	2.9%
Pacific	6.8%	7.5%	5.4%	6.9%	5.3%	1.7%
South Atlantic	8.4%	9.5%	7.7%	8.8%	5.8%	2.3%
West North Central	7.9%	9.1%	7.1%	7.9%	4.7%	2.5%
West South Central	7.7%	9.6%	6.6%	9.0%	5.8%	2.4%
National	8.1%	9.3%	7.1%	8.7%	5.6%	2.3%

A2.3. Regional median energy burdens based on race/ethnicity, age, and tenure status

Region	White (non-Hispanic)	Black	Hispanic	Older adults (65+ years)	Renter	Owner
East North Central	3.4%	5.1%	3.4%	4.7%	4.2%	3.3%
East South Central	4.0%	6.2%	5.0%	5.7%	5.3%	4.0%
Middle Atlantic	3.2%	4.4%	4.5%	4.8%	3.8%	3.2%
Mountain	2.6%	3.3%	3.7%	3.8%	3.0%	2.8%
New England	3.4%	4.0%	4.6%	4.8%	3.6%	3.5%
Pacific	2.1%	3.2%	3.0%	3.3%	2.5%	2.2%
South Atlantic	2.9%	4.0%	3.4%	4.4%	3.5%	3.0%
West North Central	3.0%	4.6%	3.3%	3.9%	3.9%	2.9%
West South Central	2.9%	4.0%	4.0%	4.4%	3.6%	3.1%
National	2.9%	4.2%	3.5%	4.2%	3.4%	3.0%

A2.4. Regional median energy burdens based on building type

Region	Single family	Multifamily (5+ units)	Low-income multifamily (5+ units, ≤200% FPL)	Built before 1980	Built after 1980
East North Central	3.6%	3.0%	6.0%	4.0%	2.9%
East South Central	4.3%	3.9%	6.6%	4.9%	3.9%
Middle Atlantic	3.5%	2.5%	6.9%	3.6%	2.9%
Mountain	2.9%	2.3%	4.5%	3.3%	2.7%
New England	3.6%	2.4%	5.6%	3.7%	3.1%
Pacific	2.4%	1.9%	5.3%	2.3%	2.3%
South Atlantic	3.2%	2.5%	5.8%	3.6%	2.9%
West North Central	3.1%	2.6%	4.7%	3.4%	2.7%
West South Central	3.3%	2.6%	5.8%	3.9%	3.0%
National	3.1%	2.4%	5.6%	3.4%	2.8%

A2.5. Regional upper-quartile energy burdens for income-based groups (25% of households in each group have a burden above the upper-quartile threshold)

Region	Low-income (≤200% FPL)	Low-income with older adults (65+)	Low-income with child under 6	Low-income with disability	Low-income multifamily	Non-low-income (>200% FPL)
East North Central	16.4%	17.6%	14.2%	15.9%	10.6%	3.9%
East South Central	15.7%	15.7%	18.7%	17.2%	12.0%	4.2%
Middle Atlantic	17.6%	20.1%	15.6%	18.5%	12.9%	4.0%
Mountain	12.0%	15.3%	9.6%	13.6%	8.4%	3.3%
New England	19.3%	21.7%	15.4%	19.2%	10.8%	4.5%
Pacific	12.0%	13.7%	10.2%	12.0%	9.2%	2.8%
South Atlantic	14.7%	15.9%	12.4%	15.7%	10.0%	3.6%
West North Central	14.1%	14.5%	13.7%	14.6%	8.7%	3.6%
West South Central	12.9%	17.5%	10.1%	16.5%	10.2%	3.5%
National	14.4%	16.3%	12.0%	15.6%	10.1%	3.6%

A2.6. Regional upper-quartile energy burdens based on race/ethnicity, age, and tenure status (25% of households in each group have a burden above the upper-quartile threshold)

Region	White (non-Hispanic)	Black	Hispanic	Older adults (65+ years)	Renter	Owner
East North Central	6.4%	10.0%	6.1%	8.4%	8.4%	6.1%
East South Central	7.4%	12.3%	9.2%	10.3%	10.9%	7.2%
Middle Atlantic	6.2%	9.8%	8.6%	9.3%	8.0%	6.1%
Mountain	4.8%	6.3%	6.2%	7.0%	5.7%	4.9%
New England	6.3%	8.1%	9.3%	9.5%	7.8%	6.0%
Pacific	4.1%	6.5%	5.6%	6.4%	5.1%	4.1%
South Atlantic	5.5%	8.0%	6.2%	8.4%	7.4%	5.5%
West North Central	5.5%	9.3%	6.1%	7.3%	7.8%	5.2%
West South Central	5.1%	7.6%	7.1%	8.6%	7.3%	5.4%
National	5.5%	8.4%	6.5%	8.1%	7.1%	5.4%

A2.7. Regional upper-quartile energy burdens based on building type (25% of households in each group have a burden above the upper-quartile threshold)

Region	Single family	Multifamily (5+ units)	Low-income multifamily (≤200% FPL, 5+ units)	Built before 1980	Built after 1980
East North Central	6.6%	6.5%	10.6%	7.4%	5.7%
East South Central	7.8%	8.2%	12.0%	9.6%	7.5%
Middle Atlantic	6.7%	6.5%	12.9%	7.0%	5.9%
Mountain	5.0%	4.7%	8.4%	5.9%	4.8%
New England	6.4%	6.1%	10.8%	7.2%	5.6%
Pacific	4.4%	4.3%	9.2%	4.7%	4.3%
South Atlantic	6.0%	5.3%	10.0%	7.2%	5.5%
West North Central	5.7%	5.5%	8.7%	6.4%	5.1%
West South Central	5.9%	5.4%	10.2%	7.4%	5.2%
National	5.8%	5.3%	10.1%	6.7%	5.3%

Appendix A.3—Metro-Level Energy Burden Data

A3.1. Metro-level energy burdens, including sample sizes for each city, median energy burdens, median monthly energy bill, and percentage with high burden and severe burden

Metro area	Sample size	Median energy burden	Median annual income	Median annual energy expenditures	Upper-quartile energy burden	High burden percentage (>6%)	Severe burden percentage (>10%)
Atlanta	1,957	3.5%	$60,000	$2,280	6.5%	28%	14%
Baltimore	1,741	3.0%	$75,100	$2,280	5.5%	23%	11%
Birmingham	1,755	4.2%	$53,300	$2,280	7.4%	34%	18%
Boston	1,728	3.1%	$81,925	$2,640	5.8%	24%	12%
Chicago	1,788	2.7%	$65,350	$1,800	4.8%	20%	10%
Dallas	2,472	2.9%	$60,000	$1,920	4.9%	19%	8%
Detroit	1,917	3.8%	$57,000	$2,160	6.9%	30%	16%
Houston	2,164	3.0%	$60,000	$1,800	5.3%	21%	11%
Las Vegas	1,968	2.8%	$54,700	$1,560	4.8%	18%	10%
Los Angeles	2,351	2.2%	$61,900	$1,440	4.4%	17%	9%
Miami	1,978	3.0%	$48,050	$1,440	5.5%	23%	12%
Minneapolis	1,943	2.2%	$81,000	$1,920	3.6%	12%	5%
New York City	1,510	2.9%	$67,500	$1,920	6.0%	25%	15%
Oklahoma City	2,111	3.3%	$52,000	$1,800	5.8%	24%	11%
Philadelphia	1,852	3.2%	$66,500	$2,160	6.3%	26%	14%
Phoenix	2,000	3.0%	$60,000	$1,800	5.2%	21%	10%
Richmond	1,933	2.6%	$69,000	$1,920	4.7%	17%	9%
Riverside	2,070	3.6%	$58,750	$2,160	6.7%	29%	15%
Rochester	1,807	3.8%	$56,000	$2,160	6.7%	29%	15%
San Antonio	2,014	3.0%	$55,000	$1,800	5.4%	22%	11%
San Francisco	1,950	1.4%	$100,000	$1,440	2.9%	10%	6%
San Jose	2,043	1.5%	$109,000	$1,560	2.9%	11%	6%
Seattle	2,162	1.8%	$79,800	$1,440	3.3%	11%	6%
Tampa	1,701	2.8%	$52,000	$1,560	5.3%	21%	11%
Washington, DC	2,214	2.0%	$100,000	$2,160	3.9%	14%	7%
National	53,539	3.1%	$58,000	$1,800	6.0%	25%	13%

A3.2. Metro-level median energy burdens for income-based groups

Metro area	Low-income (≤200% FPL)	Low-income with older adults (65+)	Low-income with child under 6	Low-income with disability	Low-income multifamily (5+ units, ≤200% FPL)	Non-low-income (>200% FPL)
Atlanta	9.7%	12.6%	8.1%	10.4%	6.6%	2.7%
Baltimore	10.5%	11.4%	7.8%	10.0%	7.5%	2.6%
Birmingham	10.9%	12.9%	9.3%	10.7%	6.8%	3.0%
Boston	10.1%	11.8%	9.5%	10.4%	6.6%	2.6%
Chicago	8.0%	9.5%	5.9%	8.0%	6.4%	2.1%
Dallas	6.7%	10.0%	6.0%	8.1%	5.0%	2.4%
Detroit	10.2%	12.0%	8.6%	10.7%	6.0%	2.8%
Houston	7.1%	9.9%	5.8%	9.6%	5.8%	2.2%
Las Vegas	6.5%	8.3%	5.0%	6.5%	5.3%	2.2%
Los Angeles	6.0%	6.4%	4.9%	6.1%	4.8%	1.6%
Miami	6.9%	8.0%	5.0%	7.6%	5.5%	2.1%
Minneapolis	6.6%	8.7%	4.7%	7.0%	4.3%	2.0%
New York City	9.3%	11.4%	7.5%	11.0%	8.0%	2.1%
Oklahoma City	7.8%	9.5%	6.1%	8.7%	6.5%	2.6%
Philadelphia	9.5%	10.4%	8.1%	10.1%	6.5%	2.4%
Phoenix	7.0%	8.3%	5.6%	7.3%	4.6%	2.4%
Richmond	8.2%	10.3%	6.9%	8.4%	5.0%	2.3%
Riverside	8.7%	10.6%	6.7%	9.6%	6.1%	2.7%
Rochester	9.5%	10.1%	7.9%	9.4%	6.0%	2.9%
San Antonio	7.4%	9.5%	6.0%	8.6%	4.8%	2.4%
San Francisco	6.1%	7.0%	4.7%	6.6%	4.9%	1.2%
San Jose	6.5%	8.1%	4.4%	7.6%	4.7%	1.2%
Seattle	6.0%	6.8%	4.4%	6.0%	4.1%	1.6%
Tampa	7.2%	8.0%	5.6%	8.0%	4.9%	2.1%
Washington, DC	7.5%	9.3%	5.9%	8.3%	5.2%	1.8%
National	8.1%	9.3%	7.1%	8.7%	5.6%	2.3%

A3.3. Metro-level median energy burdens based on race/ethnicity, age, and tenure status

Metro area	White (non-Hispanic)	Black	Hispanic	Older adults (65+)	Renter	Owner
Atlanta	3.1%	4.1%	4.7%	5.1%	3.7%	3.4%
Baltimore	2.8%	3.8%	3.3%	4.1%	3.2%	2.9%
Birmingham	3.8%	5.6%	4.8%	5.8%	5.2%	3.9%
Boston	3.0%	3.7%	3.6%	4.4%	3.2%	3.0%
Chicago	2.4%	4.1%	3.0%	3.7%	3.1%	2.5%
Dallas	2.6%	3.3%	3.8%	3.8%	2.9%	3.0%
Detroit	3.5%	5.3%	4.5%	5.2%	4.6%	3.6%
Houston	2.5%	3.5%	3.4%	4.1%	3.3%	2.7%
Las Vegas	2.7%	3.2%	3.0%	3.4%	3.0%	2.7%
Los Angeles	1.8%	3.6%	2.6%	3.2%	2.4%	2.1%
Miami	2.5%	3.4%	3.1%	4.2%	3.1%	2.8%
Minneapolis	2.2%	2.6%	2.7%	3.0%	2.3%	2.2%
New York City	2.6%	3.6%	3.8%	4.2%	3.3%	2.7%
Oklahoma City	3.1%	3.9%	4.2%	4.0%	3.9%	3.1%
Philadelphia	2.9%	4.4%	5.2%	4.4%	3.9%	3.0%
Phoenix	2.8%	3.2%	3.6%	4.0%	2.8%	3.1%
Richmond	2.4%	3.4%	2.9%	3.5%	2.9%	2.6%
Riverside	3.4%	3.9%	3.7%	5.1%	4.0%	3.4%
Rochester	3.6%	5.1%	5.4%	4.8%	4.3%	3.6%
San Antonio	2.7%	3.1%	3.4%	4.1%	3.1%	3.0%
San Francisco	1.2%	2.4%	1.2%	2.4%	1.4%	1.4%
San Jose	1.4%	1.8%	1.9%	2.4%	1.5%	1.5%
Seattle	1.8%	2.3%	2.0%	2.4%	1.8%	1.8%
Tampa	2.6%	3.6%	3.5%	3.8%	2.8%	2.9%
Washington, DC	1.7%	2.9%	2.7%	2.9%	2.0%	2.0%
National	2.9%	4.2%	3.5%	4.2%	3.4%	3.0%

A3.4. Metro-level median energy burdens based on building type

Metro area	Single family	Multifamily (5+ units)	Low-income multifamily (5+ units, ≤200% FPL)	Built before 1980	Built after 1980
Atlanta	3.7%	2.5%	6.6%	4.5%	3.3%
Baltimore	3.2%	2.5%	7.5%	3.6%	2.4%
Birmingham	4.1%	3.5%	6.8%	5.1%	3.6%
Boston	3.1%	2.2%	6.6%	3.2%	2.6%
Chicago	2.6%	2.7%	6.4%	2.9%	2.2%
Dallas	3.1%	2.2%	5.0%	3.5%	2.7%
Detroit	3.8%	2.5%	6.0%	4.3%	3.0%
Houston	3.0%	2.5%	5.8%	3.4%	2.7%
Las Vegas	2.8%	2.4%	5.3%	3.6%	2.7%
Los Angeles	2.3%	2.1%	4.8%	2.3%	2.1%
Miami	2.9%	2.9%	5.5%	3.3%	2.6%
Minneapolis	2.3%	1.8%	4.3%	2.5%	2.0%
New York City	3.0%	2.4%	8.0%	3.0%	2.4%
Oklahoma City	3.2%	3.3%	6.5%	3.8%	2.9%
Philadelphia	3.3%	2.7%	6.5%	3.6%	2.5%
Phoenix	3.1%	2.1%	4.6%	3.6%	2.8%
Richmond	2.6%	2.1%	5.0%	3.1%	2.3%
Riverside	3.5%	3.9%	6.1%	4.3%	3.3%
Rochester	3.7%	3.2%	6.0%	4.0%	3.4%
San Antonio	3.0%	2.6%	4.8%	3.9%	2.7%
San Francisco	1.5%	1.3%	4.9%	1.4%	1.4%
San Jose	1.6%	1.2%	4.7%	1.6%	1.3%
Seattle	1.9%	1.5%	4.1%	2.0%	1.7%
Tampa	2.8%	2.2%	4.9%	3.3%	2.5%
Washington, DC	2.2%	1.4%	5.2%	2.3%	1.9%
National	3.1%	2.4%	5.6%	3.4%	2.8%

A3.5. Metro-level upper-quartile energy burdens for income-based groups (25% of households in each group have a burden above the upper-quartile threshold)

Metro area	Low-income (≤200% FPL)	Low-income with older adults (65+)	Low-income with child under 6	Low-income with disability	Low-income multifamily	Non-low-income (>200% FPL)
Atlanta	16.2%	19.1%	12.8%	17.9%	11.7%	4.1%
Baltimore	21.7%	34.0%	10.9%	27.1%	5.5%	3.8%
Birmingham	18.3%	20.0%	17.1%	17.7%	13.9%	4.6%
Boston	18.6%	21.8%	16.0%	21.4%	11.7%	4.2%
Chicago	15.1%	17.5%	11.2%	13.2%	12.7%	3.1%
Dallas	11.4%	17.1%	8.5%	15.4%	7.9%	3.6%
Detroit	18.8%	21.2%	13.6%	19.8%	9.6%	4.3%
Houston	12.2%	20.2%	9.0%	22.0%	9.8%	3.2%
Las Vegas	13.8%	21.8%	8.0%	13.7%	10.9%	3.2%
Los Angeles	10.4%	11.4%	8.4%	11.2%	8.7%	2.6%
Miami	11.2%	13.3%	10.0%	13.0%	10.0%	3.0%
Minneapolis	12.2%	14.8%	6.9%	12.6%	7.7%	2.9%
New York City	16.8%	21.8%	14.1%	18.6%	15.0%	3.4%
Oklahoma City	12.5%	14.0%	9.9%	12.4%	10.2%	3.7%
Philadelphia	19.1%	24.9%	14.7%	20.0%	12.1%	3.8%
Phoenix	11.9%	15.3%	9.2%	12.7%	7.3%	3.5%
Richmond	15.6%	22.0%	10.4%	19.2%	8.8%	3.3%
Riverside	15.0%	16.6%	10.7%	16.5%	9.9%	3.9%
Rochester	15.9%	20.0%	14.0%	14.7%	9.9%	4.3%
San Antonio	13.3%	16.6%	9.2%	16.2%	9.2%	3.5%
San Francisco	14.3%	14.3%	8.5%	14.4%	11.0%	2.0%
San Jose	12.5%	14.9%	7.6%	14.9%	8.9%	2.0%
Seattle	10.9%	12.0%	9.2%	9.9%	6.8%	2.4%
Tampa	12.1%	12.1%	10.7%	12.7%	9.2%	3.2%
Washington, DC	13.5%	17.6%	8.9%	15.0%	9.1%	2.9%
National	14.4%	16.3%	12.0%	15.6%	10.1%	3.6%

A3.6. Metro-level upper-quartile energy burdens based on race/ethnicity, age, and tenure status (25% of households in each group have a burden above the upper-quartile threshold)

Metro area	White (non-Hispanic)	Black	Hispanic	Older adults (65+)	Renter	Owner
Atlanta	5.4%	8.1%	7.4%	9.8%	7.2%	6.2%
Baltimore	5.0%	8.3%	4.9%	8.0%	6.7%	5.1%
Birmingham	6.7%	11.8%	8.7%	10.7%	10.4%	6.8%
Boston	5.6%	8.1%	7.7%	9.0%	6.8%	5.6%
Chicago	4.2%	8.5%	4.9%	7.5%	6.0%	4.4%
Dallas	4.3%	5.8%	6.0%	7.0%	5.1%	4.8%
Detroit	6.3%	9.4%	7.2%	9.0%	8.9%	6.3%
Houston	4.4%	6.6%	6.1%	8.0%	6.2%	4.8%
Las Vegas	4.6%	6.1%	5.0%	6.1%	5.3%	4.3%
Los Angeles	3.6%	6.5%	5.0%	6.1%	5.1%	3.8%
Miami	4.4%	6.9%	5.8%	8.3%	6.4%	5.0%
Minneapolis	3.5%	4.4%	4.5%	5.4%	4.2%	3.5%
New York City	5.4%	8.2%	7.9%	10.1%	7.2%	5.3%
Oklahoma City	5.4%	7.4%	6.6%	7.7%	6.8%	5.2%
Philadelphia	5.2%	10.2%	9.2%	8.4%	7.9%	5.5%
Phoenix	4.8%	6.2%	6.0%	7.0%	5.2%	5.2%
Richmond	4.1%	7.0%	5.8%	6.8%	5.5%	4.4%
Riverside	6.7%	7.3%	6.9%	9.2%	7.2%	6.4%
Rochester	6.2%	11.6%	11.4%	9.0%	8.1%	6.1%
San Antonio	4.6%	5.2%	6.4%	7.9%	5.5%	5.3%
San Francisco	2.5%	5.3%	3.6%	4.7%	3.0%	2.8%
San Jose	2.8%	3.7%	3.4%	5.0%	3.1%	2.8%
Seattle	3.2%	4.5%	4.1%	5.1%	3.6%	3.2%
Tampa	5.0%	7.1%	6.3%	6.5%	5.6%	5.2%
Washington, DC	3.0%	5.1%	5.1%	6.0%	4.4%	3.6%
National	5.5%	8.4%	6.5%	8.1%	7.1%	5.4%

A3.7. Metro-level upper-quartile energy burdens based on building type (25% of households in each group have a burden above the upper-quartile threshold)

Metro area	Single family	Multifamily (5+ units)	Low-income multifamily (≤200% FPL, 5+ units)	Built before 1980	Built after 1980
Atlanta	6.6%	5.3%	11.7%	8.1%	5.8%
Baltimore	5.5%	5.5%	5.5%	6.9%	4.0%
Birmingham	7.3%	6.5%	13.9%	9.7%	6.3%
Boston	5.6%	5.6%	11.7%	6.2%	4.9%
Chicago	4.5%	5.3%	12.7%	5.5%	4.0%
Dallas	5.1%	4.2%	7.9%	6.0%	4.6%
Detroit	6.8%	6.0%	9.6%	7.5%	5.7%
Houston	5.1%	5.1%	9.8%	6.1%	4.8%
Las Vegas	4.7%	4.7%	10.9%	6.7%	4.4%
Los Angeles	4.4%	4.4%	8.7%	4.5%	4.1%
Miami	5.2%	5.5%	10.0%	6.2%	4.8%
Minneapolis	3.6%	3.3%	7.7%	3.9%	3.3%
New York City	6.3%	6.6%	15.0%	5.9%	6.4%
Oklahoma City	5.5%	6.8%	10.2%	6.9%	4.7%
Philadelphia	6.2%	5.8%	12.1%	7.0%	4.9%
Phoenix	5.1%	4.2%	7.3%	6.0%	4.6%
Richmond	4.7%	4.0%	8.8%	6.0%	3.9%
Riverside	6.5%	6.9%	9.9%	7.8%	5.8%
Rochester	6.5%	6.3%	9.9%	7.1%	5.9%
San Antonio	5.5%	4.3%	9.2%	7.5%	4.5%
San Francisco	3.0%	2.6%	11.0%	2.9%	2.8%
San Jose	3.0%	2.6%	8.9%	3.1%	2.5%
Seattle	3.2%	3.2%	6.8%	3.6%	3.1%
Tampa	5.2%	4.4%	9.2%	6.5%	4.5%
Washington, DC	4.0%	3.2%	9.1%	4.5%	3.2%
National	5.8%	5.3%	10.1%	6.7%	5.3%

APPENDIX B.
High and Severe Energy Burdens

This section includes 2017 population data from the American Housing Survey (AHS) Table Creator for both national and metropolitan statistical area samples. www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html.

Appendix B.1—National High and Severe Energy Burdens

B1.1. Total national households in each subgroup, and each subgroup's total households with a high energy burden (≥6%) and total households with severe energy burden (≥10%)

Category	Subgroup	Total households	Percentage highly burdened (≥6%)	Total highly burdened households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened households (≥10%)
Income	All households	121,560,000	25%	30,585,830	13%	15,861,674
	Low-income (≤200% FPL)	38,551,000	67%	25,776,144	40%	15,383,432
	Non-low-income (>200% FPL)	83,009,000	6%	5,214,246	1%	738,779
Race/ ethnicity	Black	16,552,000	36%	5,995,213	21%	3,469,788
	Native American	1,483,000	36%	541,155	19%	283,884
	Hispanic	16,496,000	28%	4,572,335	14%	2,250,966
	White (non-Hispanic)	80,550,000	23%	21,924,520	11%	10,485,640
Age	Older adults (65+)	34,929,000	36%	12,487,949	19%	6,701,933
Tenure	Renters	43,993,000	30%	13,218,332	17%	7,290,945
	Owners	77,567,000	22%	17,174,847	11%	8,431,501
Housing type	Low-income multifamily (5+ units) and low-income (≤200% FPL)	9,345,000	47%	4,413,429	26%	2,408,442
	Small multifamily (2–4 units)	8,363,000	47%	3,949,653	26%	2,155,356
	Manufactured homes	6,727,000	45%	2,999,580	25%	1,709,320
	Built before 1980	55,723,000	29%	15,911,480	15%	8,392,366
	Single family	85,791,000	24%	20,831,649	12%	10,476,575
	Multifamily (5+ units)	20,605,000	22%	4,572,668	12%	2,449,125
	Built after 1980	65,838,000	21%	14,114,223	11%	7,137,071

Appendix B.2—Regional High and Severe Energy Burdens

B2.1. Total households in each region, and each region's total households with a high energy burden (≥6%) and total households with severe energy burden (≥10%)

Region	Total households in region	Percentage highly burdened (≥6%)	Total highly burdened households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened households (≥10%)
East North Central	18,522,000	29%	5,371,380	15%	2,778,300
East South Central	7,417,000	38%	2,818,460	21%	1,557,570
Middle Atlantic	16,019,000	29%	4,645,510	16%	2,563,040
Mountain	8,916,000	21%	1,872,360	11%	980,760
New England	5,809,000	29%	1,684,610	15%	871,350
Pacific	18,305,000	18%	3,294,900	9%	1,647,450
South Atlantic	23,974,000	26%	6,233,240	14%	3,356,360
West North Central	8,527,000	25%	2,131,750	12%	1,023,240
West South Central	14,070,000	25%	3,517,500	13%	1,829,100
National	121,560,000	25%	30,585,830	13%	15,861,674

B2.2. Total low-income households in each region, and each region's total low-income households with a high energy burden (≥6%) and total low-income households with severe energy burden (≥10%)

Region	Total low-income households in region	Percentage highly burdened (≥6%)	Total highly burdened low-income households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened low-income households (≥10%)
East North Central	5,979,000	74%	4,424,460	45%	2,690,550
East South Central	2,976,000	74%	2,202,240	46%	1,368,960
Middle Atlantic	4,827,000	72%	3,475,440	48%	2,316,960
Mountain	2,719,000	58%	1,577,020	33%	897,270
New England	1,621,000	75%	1,215,750	52%	842,920
Pacific	5,064,000	57%	2,886,480	33%	1,671,120
South Atlantic	8,042,000	69%	5,548,980	41%	3,297,220
West North Central	2,297,000	66%	1,516,020	39%	895,830
West South Central	5,026,000	66%	3,317,160	36%	1,809,360
National	38,551,000	67%	25,776,144	40%	15,383,432

B2.3. Total Black households in each region, and each region's total Black households with a high energy burden (≥6%) and total Black households with severe energy burden (≥10%)

Region	Total Black households in region	Percentage highly burdened (≥6%)	Total highly burdened Black households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened Black households (≥10%)
East North Central	2,336,000	43%	1,004,480	25%	584,000
East South Central	1,595,000	51%	813,450	31%	494,450
Middle Atlantic	2,437,000	38%	926,060	25%	609,250
Mountain	359,000	27%	96,930	13%	46,670
New England	401,000	33%	132,330	17%	68,170
Pacific	1,077,000	26%	280,020	15%	161,550
South Atlantic	5,485,000	35%	1,919,750	20%	1,097,000
West North Central	585,000	40%	234,000	24%	140,400
West South Central	2,277,000	34%	774,180	19%	432,630
National	16,552,000	36%	5,995,213	21%	3,469,788

B2.4. Total Hispanic households in each region, and each region's total Hispanic households with a high energy burden (≥6%) and total Hispanic households with severe energy burden (≥10%)

Region	Total Hispanic households in region	Percentage highly burdened (≥6%)	Total highly burdened Hispanic households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened Hispanic households (≥10%)
East North Central	1,083,000	26%	281,580	12%	129,960
East South Central	197,000	38%	74,860	23%	45,310
Middle Atlantic	2,052,000	38%	779,760	22%	451,440
Mountain	1,721,000	27%	464,670	13%	223,730
New England	563,000	40%	225,200	23%	129,490
Pacific	4,466,000	23%	1,027,180	11%	491,260
South Atlantic	2,695,000	26%	700,700	12%	323,400
West North Central	360,000	26%	93,600	15%	54,000
West South Central	3,359,000	31%	1,041,290	15%	503,850
National	16,496,000	28%	4,572,335	14%	2,250,966

B2.5. Total older adult (65+) households in each region, and each region's total older adult (65+) households with a high energy burden (≥6%) and total older adult (65+) households with severe energy burden (≥10%)

Region	Total older adult (65+) households in MSA	Percentage highly burdened (≥6%)	Total highly burdened older adult households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened older adult households (≥10%)
East North Central	4,711,000	39%	1,837,290	20%	942,200
East South Central	1,902,000	49%	931,980	26%	494,520
Middle Atlantic	4,228,000	41%	1,733,480	23%	972,440
Mountain	2,258,000	30%	677,400	15%	338,700
New England	1,578,000	41%	646,980	24%	378,720
Pacific	4,328,000	27%	1,168,560	14%	605,920
South Atlantic	6,402,000	37%	2,368,740	21%	1,344,420
West North Central	2,202,000	32%	704,640	17%	374,340
West South Central	3,058,000	37%	1,131,460	21%	642,180
National	34,929,000	36%	12,487,949	19%	6,701,933

B2.6. Total renting households in each region, and each region's total renting households with a high energy burden (≥6%) and total renting households with severe energy burden (≥10%)

Region	Total renting households in region	Percentage highly burdened (≥6%)	Total highly burdened renting households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened renting households (≥10%)
East North Central	5,945,000	37%	2,199,650	21%	1,248,450
East South Central	2,458,000	46%	1,130,680	28%	688,240
Middle Atlantic	6,279,000	34%	2,134,860	21%	1,318,590
Mountain	3,091,000	24%	741,840	12%	370,920
New England	2,092,000	34%	711,280	19%	397,480
Pacific	7,910,000	21%	1,661,100	11%	870,100
South Atlantic	8,395,000	31%	2,602,450	17%	1,427,150
West North Central	2,616,000	34%	889,440	19%	497,040
West South Central	5,207,000	31%	1,614,170	17%	885,190
National	43,993,000	30%	13,218,332	17%	7,290,945

Appendix B.3—Metro Area High and Severe Energy Burdens

B3.1. Total households in each MSA, and each MSA's total households with a high energy burden (≥6%) and total households with severe energy burden (≥10%)

Metro area	Total households in MSA	Percentage highly burdened (≥6%)	Total highly burdened households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened households (≥10%)
Atlanta	2,108,800	28%	589,430	14%	287,711
Baltimore	1,047,600	23%	237,681	11%	120,345
Birmingham	447,000	34%	153,330	18%	80,995
Boston	1,853,800	24%	447,358	12%	230,652
Chicago	3,526,500	20%	704,117	10%	362,906
Dallas	2,564,700	19%	483,475	8%	216,838
Detroit	1,723,300	30%	518,698	16%	269,687
Houston	2,329,000	21%	499,379	11%	249,689
Las Vegas	798,600	18%	145,680	10%	80,347
Los Angeles	4,395,700	17%	768,453	9%	390,770
Miami	2,090,600	23%	476,674	12%	249,435
Minneapolis	1,379,600	12%	159,048	5%	71,714
New York City	7,428,000	25%	1,859,460	15%	1,111,740
Oklahoma City	515,900	24%	124,637	11%	57,920
Philadelphia	2,308,400	26%	609,507	14%	332,798
Phoenix	1,685,600	21%	351,448	10%	165,189
Richmond	489,500	17%	85,086	9%	46,342
Riverside	1,314,500	29%	382,285	15%	197,493
Rochester	439,700	29%	127,262	15%	64,726
San Antonio	805,700	22%	176,022	11%	88,011
San Francisco	1,706,200	10%	170,620	6%	100,622
San Jose	657,700	11%	71,468	6%	38,953
Seattle	1,485,700	11%	170,423	6%	83,837
Tampa	1,182,800	21%	248,937	11%	127,945
Washington, DC	2,178,800	14%	299,167	7%	149,583
National	120,062,818	25%	30,585,830	13%	15,861,674

B3.2. Total low-income households in each MSA, and each MSA's total low-income households with a high energy burden (≥6%) and total low-income households with severe energy burden (≥10%)

Metro area	Total low-income households in MSA	Percentage highly burdened (≥6%)	Total highly burdened low-income households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened low-income households (≥10%)
Atlanta	589,900	79%	466,021	48%	283,152
Baltimore	241,200	77%	185,724	52%	125,424
Birmingham	156,000	82%	127,920	54%	84,240
Boston	412,700	74%	305,398	51%	210,477
Chicago	1,025,400	68%	697,272	39%	399,906
Dallas	692,500	49%	339,325	31%	214,675
Detroit	551,700	80%	441,360	51%	281,367
Houston	731,100	61%	445,971	34%	248,574
Las Vegas	253,700	55%	139,535	33%	83,721
Los Angeles	1,371,300	50%	685,650	27%	370,251
Miami	820,900	57%	467,913	31%	254,479
Minneapolis	256,900	57%	146,433	32%	82,208
New York City	2,248,400	70%	1,573,880	48%	1,079,232
Oklahoma City	155,400	68%	105,672	37%	57,498
Philadelphia	652,300	74%	482,702	48%	313,104
Phoenix	507,800	59%	299,602	32%	162,496
Richmond	122,100	64%	78,144	40%	48,840
Riverside	453,700	71%	322,127	44%	199,628
Rochester	137,400	73%	100,302	46%	63,204
San Antonio	260,800	62%	161,696	35%	91,280
San Francisco	326,600	51%	166,566	32%	104,512
San Jose	121,500	54%	65,610	32%	38,880
Seattle	290,000	50%	145,000	28%	81,200
Tampa	377,900	61%	230,519	36%	136,044
Washington, DC	399,200	60%	239,520	36%	143,712
National	38,551,000	67%	25,776,144	40%	15,383,432

B3.3. Total Black households in each MSA, and each MSA's total Black households with a high energy burden (≥6%) and total Black households with severe energy burden (≥10%)

Metro area	Total Black households in MSA	Percentage highly burdened (≥6%)	Total highly burdened Black households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened Black households (≥10%)
Atlanta	789,500	36%	284,220	21%	165,795
Baltimore	324,100	34%	110,194	20%	64,820
Birmingham	137,000	47%	64,390	30%	41,100
Boston	157,900	32%	50,528	16%	25,264
Chicago	682,800	37%	252,636	21%	143,388
Dallas	466,000	25%	116,500	14%	65,240
Detroit	427,900	43%	183,997	23%	98,417
Houston	482,400	29%	139,896	15%	72,360
Las Vegas	112,600	26%	29,276	18%	20,268
Los Angeles	372,200	27%	100,494	15%	55,830
Miami	459,500	29%	133,255	18%	82,710
Minneapolis	113,000	15%	16,950	7%	7,910
New York City	1,459,600	32%	467,072	21%	306,516
Oklahoma City	61,000	32%	19,520	17%	10,370
Philadelphia	542,900	39%	211,731	25%	135,725
Phoenix	107,200	26%	27,872	15%	16,080
Richmond	153,500	28%	42,980	15%	23,025
Riverside	129,300	30%	38,790	17%	21,981
Rochester	48,000	44%	21,120	29%	13,920
San Antonio	61,500	20%	12,300	11%	6,765
San Francisco	157,900	24%	37,896	15%	23,685
San Jose	20,600	14%	2,884	11%	2,266
Seattle	94,100	14%	13,174	6%	5,646
Tampa	144,500	28%	40,460	18%	26,010
Washington, DC	631,200	21%	132,552	10%	63,120
National	16,552,000	36%	5,995,213	21%	3,469,788

B3.4. Total Hispanic households in each MSA, and each MSA's total Hispanic households with a high energy burden (≥6%) and total Hispanic households with severe energy burden (≥10%)

Metro area	Total Hispanic households in MSA	Percentage highly burdened (≥6%)	Total highly burdened Hispanic households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened Hispanic households (≥10%)
Atlanta	168,100	35%	58,835	14%	23,534
Baltimore	42,800	21%	8,988	8%	3,424
Birmingham	14,400	40%	5,760	18%	2,592
Boston	184,900	30%	55,470	17%	31,433
Chicago	561,600	19%	106,704	9%	50,544
Dallas	592,600	25%	148,150	10%	59,260
Detroit	55,200	38%	20,976	15%	8,280
Houston	706,000	25%	176,500	11%	77,660
Las Vegas	186,600	18%	33,588	10%	18,660
Los Angeles	1,589,200	20%	317,840	10%	158,920
Miami	884,800	24%	212,352	12%	106,176
Minneapolis	60,500	16%	9,680	10%	6,050
New York City	1,544,500	33%	509,685	19%	293,455
Oklahoma City	52,300	29%	15,167	16%	8,368
Philadelphia	154,100	45%	69,345	24%	36,984
Phoenix	378,300	25%	94,575	11%	41,613
Richmond	25,100	24%	6,024	11%	2,761
Riverside	579,000	31%	179,490	15%	86,850
Rochester	25,500	44%	11,220	26%	6,630
San Antonio	400,900	27%	108,243	14%	56,126
San Francisco	284,300	12%	34,116	8%	22,744
San Jose	139,200	13%	18,096	7%	9,744
Seattle	109,600	15%	16,440	7%	7,672
Tampa	188,300	27%	50,841	16%	30,128
Washington, DC	252,700	19%	48,013	6%	15,162
National	16,496,000	28%	4,572,335	14%	2,250,966

B3.5. Total older adult (65+) households in each MSA, and each MSA's total older adult (65+) households with a high energy burden (≥6%) and total older adult (65+) households with severe energy burden (≥10%)

Metro area	Total older adult (65+) households in MSA	Percentage highly burdened (≥6%)	Total highly burdened older adult households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened older adult households (≥10%)
Atlanta	490,700	44%	215,908	24%	117,768
Baltimore	107,700	34%	36,618	18%	19,386
Birmingham	127,800	48%	61,344	27%	34,506
Boston	516,400	38%	196,232	22%	113,608
Chicago	976,800	31%	302,808	16%	156,288
Dallas	540,500	29%	156,745	17%	91,885
Detroit	493,400	41%	202,294	22%	108,548
Houston	503,200	34%	171,088	20%	100,640
Las Vegas	204,400	26%	53,144	15%	30,660
Los Angeles	1,184,600	26%	307,996	14%	165,844
Miami	712,800	35%	249,480	20%	142,560
Minneapolis	339,300	22%	74,646	10%	33,930
New York City	2,162,800	39%	843,492	26%	562,328
Oklahoma City	123,800	35%	43,330	17%	21,046
Philadelphia	674,400	37%	249,528	21%	141,624
Phoenix	502,700	30%	150,810	14%	70,378
Richmond	131,100	29%	38,019	15%	19,665
Riverside	368,300	42%	154,686	24%	88,392
Rochester	133,600	39%	52,104	20%	26,720
San Antonio	188,100	35%	65,835	18%	33,858
San Francisco	498,900	18%	89,802	10%	49,890
San Jose	171,000	20%	34,200	11%	18,810
Seattle	361,100	19%	68,609	9%	32,499
Tampa	402,500	30%	120,750	14%	56,350
Washington, DC	546,800	25%	136,700	14%	76,552
National	34,929,000	36%	12,487,949	19%	6,701,933

B3.6. Total renting households in each MSA, and each MSA's total renting households with a high energy burden (≥6%) and total renting households with severe energy burden (≥10%)

Metro area	Total renting households in MSA	Percentage highly burdened (≥6%)	Total highly burdened renting households (≥6%)	Percentage severely burdened (≥10%)	Total severely burdened renting households (≥10%)
Atlanta	794,400	31%	246,264	16%	127,104
Baltimore	369,100	30%	110,730	16%	59,056
Birmingham	141,700	47%	66,599	28%	39,676
Boston	715,000	28%	200,200	15%	107,250
Chicago	1,238,200	26%	321,932	14%	173,348
Dallas	1,060,200	20%	212,040	10%	106,020
Detroit	527,300	40%	210,920	21%	110,733
Houston	896,000	27%	241,920	14%	125,440
Las Vegas	400,900	21%	84,189	12%	48,108
Los Angeles	2,280,900	21%	478,989	11%	250,899
Miami	853,900	27%	230,553	15%	128,085
Minneapolis	407,700	14%	57,078	7%	28,539
New York City	3,643,800	29%	1,056,702	19%	692,322
Oklahoma City	169,200	30%	50,760	15%	25,380
Philadelphia	614,800	35%	215,180	19%	116,812
Phoenix	593,300	21%	124,593	10%	59,330
Richmond	174,500	23%	40,135	13%	22,685
Riverside	479,300	33%	158,169	16%	76,688
Rochester	144,300	36%	51,948	20%	28,860
San Antonio	305,300	22%	67,166	11%	33,583
San Francisco	375,100	13%	48,763	8%	30,008
San Jose	272,200	12%	32,664	7%	19,054
Seattle	613,600	13%	79,768	7%	42,952
Tampa	418,000	23%	96,140	13%	54,340
Washington, DC	801,800	17%	136,306	8%	64,144
National	43,993,000	30%	13,218,332	17%	7,290,945