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Energy Hogs and Energy Angels: What Does Residential Electricity Usage Really Tell Us About Profligate Consumption?

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Abstract

Since the 1970s, high volumetric (per kilowatt-hour) electricity prices have been justified in many policy discussions as encouraging more efficient use of electricity and placing more of the cost burden on those who are less prudent in their use. The argument has been used in support of increasing-block electricity pricing, under which the price per kilowatt-hour rises as a household consumes more electricity per month. More recently, in California, opponents of a proposal to lower volumetric prices and replace the revenue through fixed monthly charges have suggested that the change would just benefit "energy hogs". In this paper, I first investigate characteristics of households who are high electricity consumers and ask how effectively such pricing targets profligate residential electricity consumption. I then look more broadly at the energy usage individuals are responsible for in the economy, how other energy usage is priced, and the role that residential electricity use plays in the overall picture. Finally, I connect the discussion of profligate direct and indirect energy consumption with the negative externalities produced, which are typically the justification for such penalty pricing.

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1 Introduction

Residential electricity prices in the US are often set with the goal of rewarding low usage and shifting the revenue burden more towards high-usage households. This is evident in increasing-block pricing and in setting relatively low fixed monthly charges while setting volumetric (per-kilowatt-hour) prices well above the marginal cost of incremental supply (Kahn, 1988). California is an extreme case, with the investor-owned utilities collecting virtually no fixed charges and setting volumetric prices at least 2-3 times higher than social marginal cost (inclusive of the damages from emissions) (Borenstein, Fowlie and Sallee, 2021). Furthermore, the fixed costs driving the differential between retail price and social marginal costs are rising rapidly in California (Elmallah, Brockway and Callaway, 2022; CPUC, 2021; JDSupra, 2023).

High volumetric prices have been justified on both efficiency and equity grounds. The efficiency argument is based on the view that high prices encourage more prudent use of electricity. This view is inconsistent with economic efficiency in places where price is already above social marginal cost, as is true in much of the US (Borenstein and Bushnell, 2022a), but it has proven to have very strong political appeal. On equity, it is often noted that wealthier households buy more electricity on average. While that is true, the correlation was never terribly strong in California (Borenstein, 2012), and has become weaker with the adoption of rooftop solar disproportionately by wealthier households (Borenstein, Fowlie and Sallee, 2022).

High volumetric prices are also frequently supported on the idea that large consumers are more profligate in their use of electricity and therefore it is appropriate to require them to pay more towards system fixed costs and state policies that are financed out of electricity rates. In the current California debate over implementing an income-graduated fixed charge (IGFC), one NGO has testified in the CPUC proceeding that "high fixed charges [result] in the ratepayers with the least efficient consumption patterns realizing the greatest amount of savings", while an industry group that includes many rooftop solar companies has filed comments arguing that increased fixed charges would hurt low-usage customers "who are aligned with California's long-standing energy conservation goals".[1]

[1]The first quote is from the rebuttal testimony of Ben Schwarz on behalf the Clean Coalition (page 2). The second quote is from comments filed by Brad Heavner on behalf of the California Solar & Storage Association (page 3). Filings are available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/demand-flexibility-rulemaking . Other vocal opponents of the proposed change have argued "the big winners will be energy hogs in the Central Valley", and "[The IGFC] will reward the energy hogs and penalize the energy misers". These quotes are taken from postings on the "Electricity Brain Trust", an online chat forum with about 700 members whose contributors are primarily consultants, industry participants, and policymakers. Nor is this attitude new in California. In 2001, then-CPUC president Loretta Lynch said on the PBS Frontline show, "What we have is a baseline concept. We take the average use of residents in a particular climate zone ... and say, 'If you can use 130 percent of baseline, your electric bill won't go up. If you use, say, up to 200 percent of baseline, you'll be paying more for that increment of power to incent you to use less. And if you use over 200 percent of baseline–basically, if you're an energy hog–then that portion over 200 percent is going to be pretty expensive.' "[2]

In this paper, I study more closely the argument that high net electricity demand by a household is a reliable indicator of less careful or efficient usage, where *net* refers to the fact that nearly all California households with distributed solar generation are billed based on total consumption minus the generation from their solar system.[3] While it is difficult to know whether a customer is consuming electricity for uses that provide low private or social value, *i.e.,* whether the customer's usage is wasteful or imprudent, it is more straightforward to ask how much of the variation across households is attributable to factors that most policymakers would agree should *not* be considered profligate. For instance, households with many occupants will use more electricity, but policymakers would generally not see such housing decisions as wasteful; more likely, just the opposite, because more occupants of a dwelling typically make it more efficient on a per capita usage basis.

Likewise, while households that install rooftop solar may be making the system generation mix less polluting, their decision to become a so-called "prosumer" doesn't address the prudence of their electricity consumption any more than if they installed a diesel generator. I also consider the climate in which the household is located and a number of demographic characteristics, such as the occupancy by young or old individuals. The idea is that these are all factors that play some role in household electricity consumption, but are generally not viewed as drivers of usage that merit disapproval or penalty.

I find that adjusting electricity usage for these factors, which few would argue qualifies a household as profligate, greatly changes the distribution of usage, and changes who would be considered an "energy hog". I also examine "energy angels", those households with low net electricity consumption, and find that they too look much more like the population as a whole after adjusting for the same factors. Overall, I find that roughly 60% to 90% of the difference in consumption between heavier users and lighter users is explained by factors that most policymakers would say are unrelated to efficiency or prudence of usage.

I then examine residential electricity consumption in the larger context of all energy usage in the economy as a whole. Virtually all energy usage in the economy is ultimately attributable to some individuals' consumption, so it seems reasonable to ask how much household net electricity consumption reveals about the overall energy usage, and GHG emissions, attributable to the activities of individuals. Although I don't reach a conclusion on that question, some simple statistics of economy-wide energy use suggest that residential electricity is a very small factor. Therefore, at the least, singling out this one form of energy use for disapproval or penalty seems misguided, particularly given how much of even that variation is driven by factors unrelated to

[3] California changed this "net metering" policy in April 2023 so that households installing distributed generation after that time would be paid a separate, and lower, price for electricity they inject into the grid than they are charged for retail electricity that they consume from the grid. However, all households that installed distributed generation before April 15, 2023 fall under a net metering policy that rewards production at, or very close to, the retail price.

the prudence or efficiency of consumption.

2 How Residential Rate Design Penalizes Heavy Usage

Residential electricity rates are structured in two ways that penalize heavy usage, one that is fairly clear to all consumers, and one that is much less obvious. By ”penalize”, I mean rates that cause some customers to pay more than others in excess of the social marginal cost of serving them. Heavy usage is penalized when the excess payments are based on the volume of consumption.

In California and in many utility areas in other states, heavy residential usage is explicitly and transparently penalized through increasing-block pricing (IBP), in which the marginal price per kWh rises with the total quantity consumed during a billing period.[4] In the past, California has had very steep IBP; the marginal price of a residential customer at the 75th percentile of consumption has been two or more times the marginal price of a customer at the 25th percentile. The structure has flattened considerably in the last five years so that ratio is now 1.25 or less on the default residential tariff.

Though some people conflate IBP with time-varying pricing, there is no time-based component to IBP, so these marginal price differences are not reflecting the time of consumption. It is true that, on average, heavier users consume a somewhat higher share of their electricity at high usage times—probably because they are more likely to use air conditioning—but Borenstein (2013) suggests that the difference in cost is just a few percentage points, nowhere near the difference in marginal price across the tiers of IBP tariffs. In addition, because that relationship is only true on average, many heavier users who are less expensive to serve per kWh are still penalized.

One frequent argument for IBP is that it will encourage conservation. From an economic point of view, however, a marginal price above social marginal cost encourages excessive conservation, just as a marginal price below social marginal cost encourages excessive consumption. In any case, whether or not IBP reduces total usage versus a flat rate that collects the same revenue depends on how much it triggers increased usage among customers who face a lower rate compared to how much it causes reduced usage among customers who face a higher rate. Ito (2014) suggests that the net effect is approximately zero.

The less obvious way in which heavy users are penalized is through volumetric rates that are above social marginal cost, even if they do not vary with usage. Setting volumetric price equal to social marginal cost (SMC) is economically efficient,[5] but two factors frequently lead to prices

[4]Borenstein and Bushnell (2022a) finds that 37% of US residential consumers face rates with increasing-block pricing.

[5]This statement is strictly true only if all other goods in the economy are priced efficiently. Borenstein and Bushnell (2022b) finds that two of the most important substitutes for electricity—natural gas and gasoline—are also mispriced. Add a social cost of carbon of $100 per metric tonne, gasoline is underpriced nearly everywhere in the

above SMC. The first is that transmission and distribution services are natural monopolies, which implies that marginal cost is below average cost, so setting price at SMC will typically not recover all of the utility's costs.[6] The second factor is that states frequently use volumetric electricity rates to fund energy policies that are not intrinsic to operation of the electric utility, such as energy efficiency programs, subsidies for low income customers and rooftop solar adopters, and R&D on new energy technologies.

Few people would disagree with the assertion that raising the retail price of electricity to fund public schools, for example, penalizes heavy electricity users. Not only does a household using more electricity not have a causal effect on the cost of public education, public education is not a direct part of supplying electricity. Similarly, the cost of energy policies funded by raising electricity prices does not increase with a household's consumption of electricity. Nor are those policies intrinsic to supplying electricity, as for instance are the fixed costs of distribution networks. Thus, funding activities that are only indirectly related to a household's consumption of electricity places the burden of those policies on households based on their consumption, essentially a tax on consumption.

When the drivers of revenue requirements are fixed costs of grid infrastructure that is intrinsic to delivery of electricity, there is less agreement on the appropriateness of raising volumetric price above SMC to cover these costs. It is clear that most of the cost of local distribution systems does not increase when households on the circuit increase their consumption, so are not part of SMC. Thus, allocation of these costs in proportion to electricity consumption can't be justified as economically efficient. Still, some people suggest allocation in proportion to consumption is the most equitable approach, even if it is not efficient, because customers who consume more are getting greater benefit from that fixed infrastructure. Borenstein (8 July 2019) unpacks this view a bit more, arguing that a more economic-grounded equity foundation would base the contributions of customers on their consumer surplus, but because that is not practical to measure, quantity consumed is used as an approximation. It is, however, not difficult to suggest real-world cases in which it would be a poor approximation, such as when a customer has very elastic demand due to an alternative technology that becomes cost-effective at a slightly higher price. Furthermore, many other government services that yield differential benefits across households—such as police, fire, and public health services—are simply financed out of the government budget and paid for

US, and natural gas is underpriced in most of the US, implying that the optimal price of electricity is likely to be below SMC. See Borenstein (20 June 2023) for further discussion of the impact of the social cost of carbon on the optimal price of electricity.

[6]For a more detailed discussion of the implications of natural monopoly, see Kahn (1988) and Borenstein (2016). Setting volumetric price equal to SMC does not always create a revenue shortfall, because utilities often are responsible for negative pollution externalities for which they are not required to pay, so setting price equal to SMC generates extra revenue towards covering fixed costs. Borenstein and Bushnell (2022a), however, shows that most utilities still charge volumetric prices above SMC for residential customers.

through income or other broad-based taxes, regardless of the benefits that any households get from the service.

3 Data

The primary data I use for studying household energy usage is the Residential Appliance Saturation Survey (RASS) created by the California Energy Commission.[7] The most recent survey took place in 2019. This dataset incorporates survey responses from about 40,000 households in California. I focus on the slightly fewer than 32,000 customers who are individually-metered and reside in the service territories of the three large investor-owned electricity utilities, Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). The survey includes utility-verified information on location, annual electricity and natural gas usage, and distributed generation at the residence, as well as extensive demographic information about the household, appliance ownership and other variables. Each observation in the RASS includes a sample weight calculated to match the overall population demographics of the utility service territory.[8] All analysis here utilizes the sample weights, though the results are similar if the data are used unweighted.

As part of the data analysis in Borenstein, Fowlie and Sallee (2022), the RASS data were augmented and extended in two important areas that I utilize here. First, the RASS includes a flag for solar installation, but does not have detailed information on the size or attributes of the installation. Through careful matching of the RASS with household billing information, the detailed installation information in Lawrence Berkeley National Laboratories' *Tracking the Sun* project database,[9] and solar generation simulation software, Borenstein, Fowlie and Sallee (2022) created estimated solar generation for every household in the RASS that has installed distributed (*i.e.,* customer-sited) solar. Second, for about one-third of the IOU-served households in the RASS, the total annual electricity consumption value is missing, including a very high share of households with solar. By matching the RASS households to 2019 customer billing data, Borenstein, Fowlie and Sallee (2022) created a consistent data series of household consumption for virtually all IOU-served, individually-metered residential customers in the RASS.

Further details on the construction of individual variables are in the appendix.

[7] https://www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study

[8] See 2019 California Residential Appliance Saturation Survey, Volume I: Methodology, available at https://webtools.dnv.com/CA_RASS/Uploads/CEC-200-2021-005-MTHLGY.pdf

[9] https://emp.lbl.gov/tracking-the-sun

4 What drives net electricity consumption?

The typical measure referenced in characterizing a household's electricity consumption as excessive or imprudent is the annual net electricity usage of the household. For at least the last four decades, California has charged households higher rates for consumption beyond certain daily levels, *i.e.,* increasing-block pricing. Over this time period, regulators and the state have also chosen to recover a widening array of state energy policy expenses through volumetric prices, effectively taxing electricity to cover these costs (Borenstein, Fowlie and Sallee, 2021). Compared to using fixed charges or paying for costs through the state budget or other local taxes, this approach particularly burdens those who consume higher net quantities of electricity at home.

These policy decisions have frequently been justified based on the assertion that high household electricity consumption indicates inefficient or imprudent household energy decisions, or that high electricity prices will induce more efficient energy decisions. To the extent that high prices are intended to yield more economically efficient levels of consumption, Borenstein and Bushnell (2022b) and Borenstein, Fowlie and Sallee (2021) have demonstrated that California prices are well above efficient levels already and raising them further is likely to reduce economic efficiency. In this paper, I attempt to shed light on the argument that high electricity consumption reveals a lack of prudence in a household's energy use.

One concern that arises with the imprudence claim is that there are many reasons a household may consume high quantities of electricity that very few people or policymakers would argue indicates excessive or profligate use. The most obvious reason is that households include differing numbers of individuals. By omitting this factor, electricity pricing favors individuals living alone, while penalizing large families or groups living together. This is particularly ironic or self-defeating, because living alone is likely to be the most inefficient form of housing when it comes to use of electricity and many other resources.

Other factors that society would likely not want to penalize are also potential drivers of household electricity consumption. The climate in the household's location will drive heating and cooling demand.[10] Some wealthy families have multiple homes and occupy any one of them less often, leading to lower usage at each home than a family that lives in one house full time. The presence of children or senior citizens increases usage on average, possibly because these people spend more time at home, and possibly because they are less tolerant of household temperature vari-

[10]The utilities in this study and their regulator do recognize that electricity demand is affected by climate, as well as heating source. In the increasing-block price schedules, the quantity a customer can purchase at the lower block price varies by climate zone, season, and whether the residence is heated primarily with electricity. The discount for the lower block, however, is small relative to the price. For a house in the hot Central Valley, the larger quantity on the lowest block saves the customer about $30 per month during the summer compared to a house in the more temperate Bay Area. Furthermore, even the lower block price is more than double social marginal cost, so the burden of covering non-marginal costs still falls to a greater extent on customers who consume larger quantities.

ation. Working from home would also increase home electricity usage. That would be offset to some extent by lower usage at the workplace, or possibly even the elimination of part or all of the workplace, but the focus on residential electricity consumption does not capture that.

Finally, a large and increasing source of differentiation across homes in net electricity use is whether they have installed distributed solar generation. Installing solar does not lower one's electricity usage or make it more prudent. In practice, a rooftop solar installation operates as part of the grid supply. There are diverse views on whether rooftop solar is a cost-effective way to generate renewable electricity, but installing solar clearly does not make a household's *consumption* more efficient.

The question that I pursue in the remainder of this section is how adjusting for these factors that are unrelated to the prudence of consumption changes how one might view households that have often been tagged as energy hogs in policy discussions. And, conversely, how such adjustments change the relative consumption of "energy angels", those who have particularly low net household electricity use. I begin by adjusting for the number of occupants, comparing net household electricity usage to net per capita electricity usage. Next, in order to observe actual usage unobscured by on-site generation, I add back in estimated distributed solar generation for those customers who have installed solar, yielding gross per capita electricity usage. Correction for local climate is done with a regression of gross per capita electricity usage on climate zone fixed effects and taking the residuals as the variation in usage that is not driven by climate. Finally, I control for a few other household demographics that would not be viewed as indicators of imprudent consumption—share of occupants who are children or senior citizens, year-round occupancy of the house, and weekly hours that an occupant works from home—by adding these variables to the regression on climate zones and again taking the residuals as usage that remains after these controls.

I also present results that include one more set of adjustments that some may consider to be conscious choices about electricity consumption, albeit ones that are generally aligned with current environmental policies. This step controls for the presence of electrical appliances that can alternatively run on fossil fuel combustion: stoves, clothes dryers, hot water heaters, space heaters, and vehicles. The vast majority of houses have these amenities, and few would argue households should do without them, so it seems that one wouldn't want to judge prudence of energy use based on whether a household powers them with electricity, rather than natural gas or gasoline. In addition, this step controls for the age of the house, based on the presumption that there are not now, nor likely to be in the near future, policies of tearing down old houses in order to reduce energy usage.

For the regression-based corrections for climate and household demographics, the residuals are added to the mean of the dependent variable to construct usage after controlling for the regressors. Thus, by construction, the mean of the resulting corrected variable is equal to the mean of the original dependent variable (because the mean of the residuals is zero) and the deviation from the mean is orthogonal to the regressors.

Such a regression approach is imperfect, because the regressors could be correlated with omitted variables that some may see as indicative of consumption prudence or imprudence, such as if people who live in hotter climates are likely to have more efficient air conditioners or senior citizens are less likely to install LED light bulbs. The RASS, however, does not include the efficiency levels of appliances and, in any case, does not have information on household *behavior* in energy consumption, such as leaving the lights on in empty rooms. Nonetheless, as will be apparent, it seems unlikely that this correlation would substantially change the conclusions.

The results are presented in two different ways to answer two somewhat different questions. First, I show where in the overall distribution of usage households who are tagged as energy hogs based on net consumption end up after each adjustment, and similarly for energy angels. Mechanically, households that begin at the top of the distribution can only move lower on average, but the extent to which they do is still useful information in understanding how different these households are after adjusting for these factors unrelated to consumption prudence. To further understand consumption of heavier versus lighter net electricity consuming households, I then calculate the ratio of average consumption between these groups with each successive control for unrelated factors. Each set of results is presented separately for the three investor-owned utilities, PG&E, SCE, and SDG&E.

4.1 Effect of adjusting for unrelated factors on distribution of usage

Figure 1 presents the distribution of the "energy hogs"—whom I designate as the the top 20% of net household electricity users[11]—in the overall distribution, first with no adjustment and then tracking the same set of customers after each subsequent adjustment. Each dot represents the average consumption of one percentile of the overall distribution, so there are 20 dots in each figure. The second line shows that focusing on per capita consumption rather than total household usage substantially changes where these households are in the overall distribution of households, now based on per capita consumption. For PG&E customers, the average net per capita consumption of the lowest 5% of the "energy hogs" (1% of all households) is at the 32nd percentile of the overall distribution of this measure, while the average net per capita consumption of the next lowest 5% of the energy hogs is at the 41st percentile, and so forth.[12] The third line shows where

[11]Results are qualitatively similar designating the top 10% or 30% as hogs.

[12]To clarify, each individual dot does not represent the consumption of the same subset of individual customers across the lines. Rather, for instance, after each adjustment the leftmost dot is the average of the group of households in the lowest 5% of those households originally designated as energy hogs, which is one percentile of the total sample.

the original "energy hogs" lie in the distribution after adding back in customer-sited distributed solar generation. The fourth line also adjusts for climate zones by regressing gross per capita consumption on climate zone fixed effects. The fifth line ads to the regression the share of household occupants who are between 18 and 65 years old, whether the house is only occupied seasonally, and the number of hours that someone in the household is reported to be working from home. The final line adds to the regression the age of the house and presence of the electrical appliances discussed above. Exact variable definitions and the regressions on which these figures are based are presented in the appendix.

It's clear from these figures that analyzing *per capita* net consumption leads to very different conclusions than the standard judgment based on household net consumption. Focusing on gross consumption rather than net, by adding back in distributed solar generation, further reduces the difference between the so-called energy hogs and other customers. Adjusting for climate also changes conclusions substantially, largely because inland customers in California (who are poorer on average) tend to use more electricity for air conditioning then those living on the coast. The adjustments for seasonal occupancy, adults between 18 and 65, and working from home make less difference, even though these variables are statistically significant in many of the regressions.

Figure 2 presents the distribution of the "energy angels", the bottom 20% of net household electricity users, in the overall distribution after each of the adjustments. After adjusting for household occupancy, distributed solar, and climate, these households don't look very different from the overall distribution of usage in the population.

For each one-percentile group of "hog" households, the average consumption is calculated and then the dot is located at the point where that average consumption falls in the overall distribution of customers.

Figure 1: Energy “Hogs” in Overall Distribution of Electricity Consumption

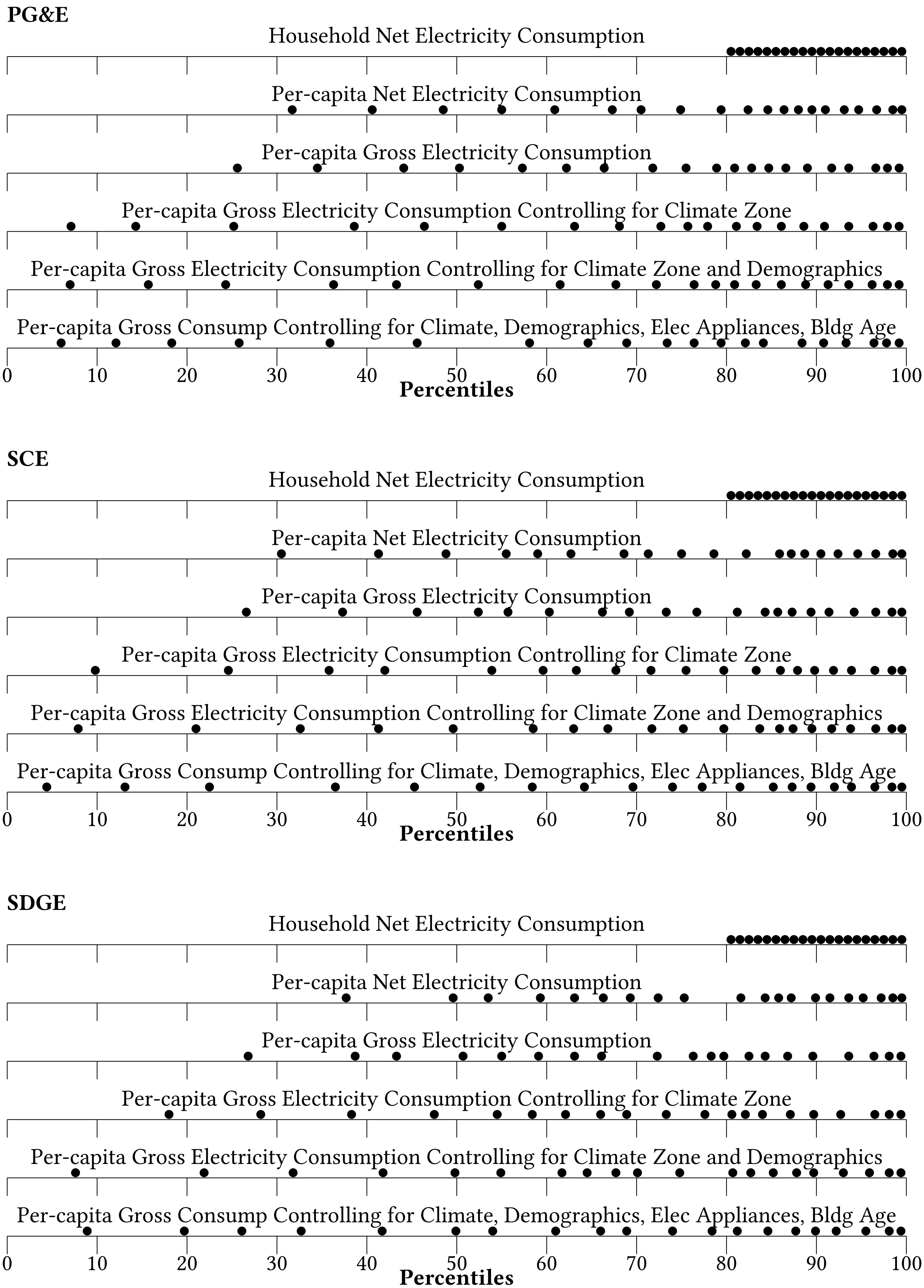


Figure 2: Energy "Angels" in Overall Distribution of Electricity Consumption

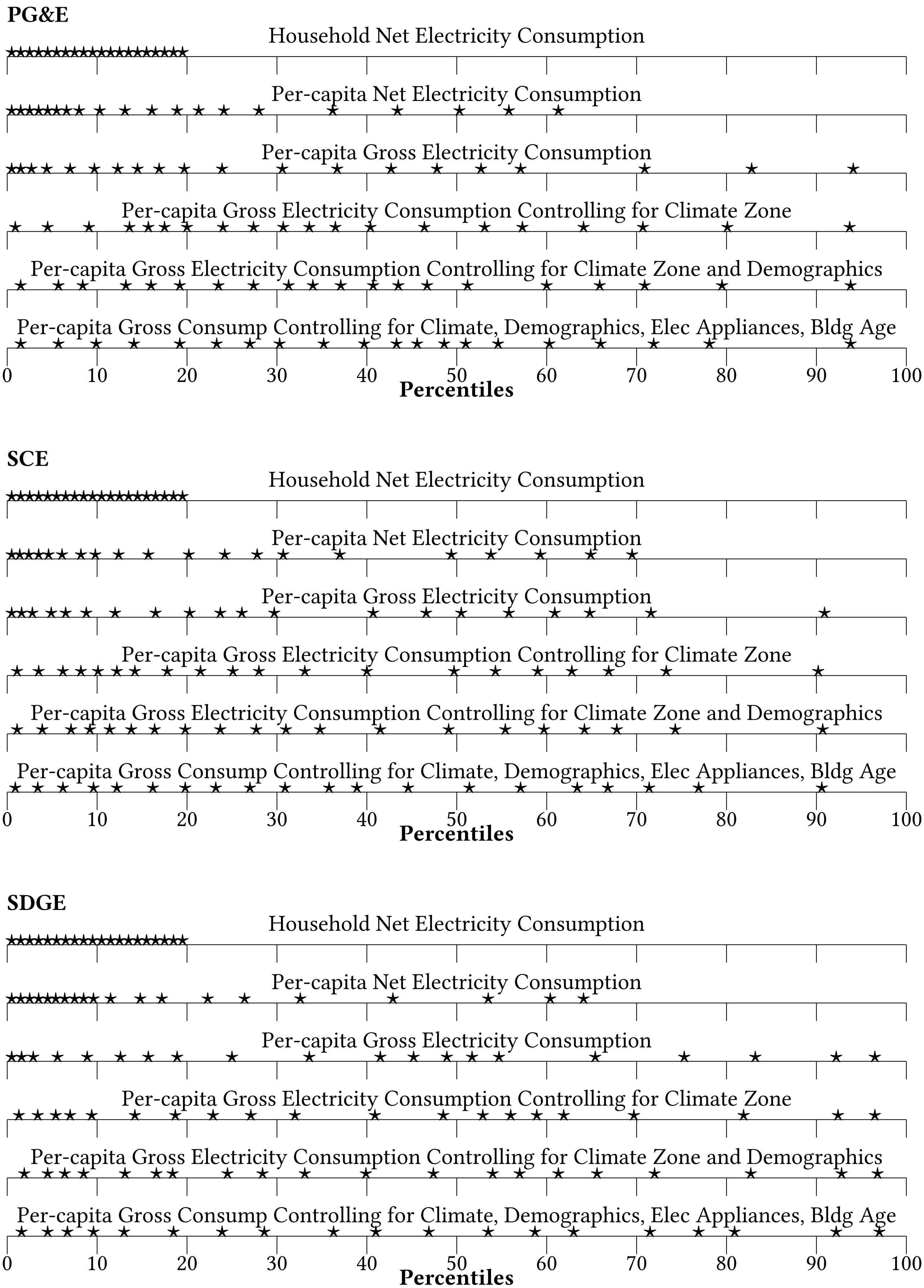


Table 1:
Ratio of Average Consumption of Above-median vs Below-median Net Consumption Households

Utility	PG&E	SCE	SDG&E
Net Household Consumption	3.10	2.68	3.09
Net Per Capita Consumption	2.33	2.02	2.21
Gross Per Capita Consumption	1.83	1.82	1.44
+ control for Climate Zone	1.55	1.69	1.38
+ control for children/seniors, seasonal, work-from-home	1.53	1.64	1.31
+ control for electric appliances and building age	1.43	1.56	1.24

NOTE: This table presents the ratio of the average consumption of households whose net consumption is above the median of all households of the utility in the RASS to the average consumption of households whose net consumption is below the median. The top line shows the ratio of average net household consumption. The second line shows the ratio of average net per capita consumption. The third line shows the ratio of average gross (after estimated distributed solar generation is added back in) per capita consumption. The lines below show the ratio of average gross per capita consumption after controlling for different factor, as explained in the text. Regressions for the last three adjustments are shown in the appendix.

4.2 The impact of adjustments on heavier versus lighter electricity users

Figures 1 and 2 are useful visual representations of how adjustments for these unrelated factors change where these "hogs" and "angels" sit in the overall distribution of customers, but they don't give quantitative measures of the differences between these customers and how the adjustments change those differences. To address that question, table 1 presents the ratios of average consumption of the customers who are above the median in net household consumption to those who are below the median in net household consumption, and how those ratios change with the same adjustments.

The top row of table 1 shows that the average consumption of PG&E residential customers who are above the median in net household consumption is 3.10 times higher than the average consumption of PG&E customers who are below the median in net household consumption. The second row shows that the ratio of consumption between those same households drops to 2.33 when calculated on a per capita basis. And the third row shows that the ratio drops to 1.83 when distributed solar generation is included. The ratio drops to 1.55 when controls for climate zone are also included. Put differently, the results for PG&E show that customers who are above median in net household consumption use 210% more electricity than customers who are below median, but expressed as per capita consumption, adjusted for distributed solar generation, and controlling for climate zone, they consume 55% more. That is, about 74% of the difference between

Table 2:
Effect of Each Adjustment in Isolation

Utility	PG&E	SCE	SDG&E
Net Per Capita Consumption	-37%	-40%	-42%
Gross Household Consumption	-40%	-23%	-67%
Control for Climate Zone	-23%	-10%	-7%
Controls for children/seniors, seasonal, work-from-home	-3%	-3%	-18%
Controls for electric appliances and building age	-15%	-10%	-15%

NOTE: For each adjustment, this table presents the decline in the proportion by which the average consumption of households whose net consumption is above the median of all households of the utility in the RASS exceeds the average consumption of households whose net consumption is below the median. Regressions for the last three adjustments are shown in the appendix.

households that are above median and those that are below median in net household consumption can be attributed to number of occupants, distributed solar generation, and climate. The share attributed to these three factors is somewhat smaller for SCE customers (59%) and somewhat larger for SDG&E customers (82%).[13]

Table 1 also demonstrates what was apparent from figures 1 and 2, that the demographic and appliance ownership adjustments have smaller effects. This is likely because only 7% of the households own an EV in this 2019 survey, 9% have electric water heaters, and 17% have electric space heating, while the other appliances constitute smaller shares of electricity usage where they are present. In addition, electric water heating and space heating is correlated with smaller square footage, rental properties, and lower-income occupants, according to the RASS.

One concern with the analysis thus far might be that the small effects of the later adjustments could be due to the order in which the adjustments are made. Table 2 shows the effect on the ratio in table 1 of carrying out each adjustment separately. Adjustment for the number of occupants in the residence and the reduced billed quantity due to distributed solar are clearly the two largest factors. Climate is the third largest factor in PG&E's Northern California service territory, but much less so in the southern part of the state.

One also might wonder if these results are driven by a few outliers, those who are either consuming large net quantities or who have completely zeroed out net consumption through distributed solar and efficiency investments. To address this concern, table 3 present a slight variation on table 1, examining the ratio of the medians, rather than the means, of higher and lower quantity consumers. For each adjustment, table 3 compares the median consumption among

[13]See Bustamante et al. (2023) for a study of the variation in electricity use among student housing in a university setting.

Table 3:
Ratio of Median Consumptions of Above-median vs Below-median Net Consumption Households

Utility	PG&E	SCE	SDG&E
Net Household Consumption	2.47	2.33	2.43
Net Per Capita Consumption	2.09	1.89	2.30
Gross Per Capita Consumption	1.76	1.74	1.44
+ control for Climate Zone	1.44	1.51	1.45
+ control for children/seniors, seasonal, work-from-home	1.39	1.45	1.32
+ control for electric appliances and building age	1.28	1.33	1.27

NOTE: This table presents the ratio of the median consumption among households whose net consumption is above the median of all households of the utility in the RASS to the median consumption among households whose net consumption is below the median. The top line shows the ratio of median net household consumption in the two groups. The second line shows the ratio of median net per capita consumption. The third line shows the ratio of median gross (after estimated distributed solar generation is added back in) per capita consumption. The lines below show the ratio of median gross per capita consumption after also controlling for different factors, as explained in the text. Regressions for the last three adjustments are shown in the appendix.

those households that are above versus below the median in net household consumption. Comparing medians lowers the share of the differences associated with the number of household occupants, distributed generation and climate somewhat, but for all three utilities these factors still constitute 59% to 70% of the difference between heavier and lighter users.

Applying this analytical approach to energy "hogs" versus "angels", as they were defined earlier, yields different ratios, but a similar conclusion. Table 4 shows the ratio of the average consumption of households in the top 20% of net consumption versus those in the bottom 20%. For PG&E, households in the top 20% consume 829% more before any adjustments and 113% more after adjusting for number of occupants, distributed solar generation, and climate. These three categories explain 86% of the difference between hogs and angels among PG&E households, 71% among SCE households, and 91% among SDG&E households. Again, the demographic and appliance adjustments have smaller effects.

4.3 Changing demographics of hogs and angels due to the adjustments

It is clear that the adjustments for factors unrelated to imprudent usage systematically moves households with many occupants, lacking distributed solar, and living in hot climates out of the top percentiles. Likewise, these adjustments tend to move such households into the "angel" percentiles. Conversely, households with distributed solar, fewer occupants, and cooler climates

Table 4:
Ratio of Average Consumption of top 20% vs bottom 20% on Net Consumption Households

Utility	PG&E	SCE	SDG&E
Net Household Consumption	9.29	6.21	11.22
Net Per Capita Consumption	5.26	3.73	6.31
Gross Per Capita Consumption	2.58	2.74	1.99
+ control for Climate Zone	2.13	2.50	1.91
+ control for children/seniors, seasonal, work-from-home	2.04	2.40	1.79
+ control for electric appliances and building age	1.86	2.22	1.68

NOTE: This table presents the ratio of the average consumption of households whose net consumption is in the top 20 percentile of all households of the utility in the RASS to the average consumption of households whose net consumption is in the bottom 20 percentile. The top line shows the ratio of average net household consumption. The second line shows the ratio of average net per capita consumption. The third line shows the ratio of average gross (after estimated distributed solar generation is added back in) per capita consumption. The lines below show the ratio of average gross per capita consumption after controlling for different factor, as explained in the text. Regressions for the last three adjustments are shown in the appendix.

are disproportionately moved up in the percentile distribution by these adjustments. So how do these adjustments change the demographics of households that fall into the top 20% and bottom 20% after each adjustment? Table 5 presents the changes for the three demographic designations that are most affected by these adjustments. It shows that designating heavy and light electricity users without making these adjustments very substantially under-represents low-income and Latinx households among the "angels" and, to a lesser extent, over-represents them among the "hogs". At the same time, basing such characterizations on net household consumption without adjustments overstates the share of white households among low users and understates their share among high users. The impact on households where English is not the primary language is similar to the impact on Latinx customers. Controlling for these factors unrelated profligacy, however, has no consistent impact on the share of Black households among high or low use customers.

5 Energy Hogs and Angels in the Larger Context

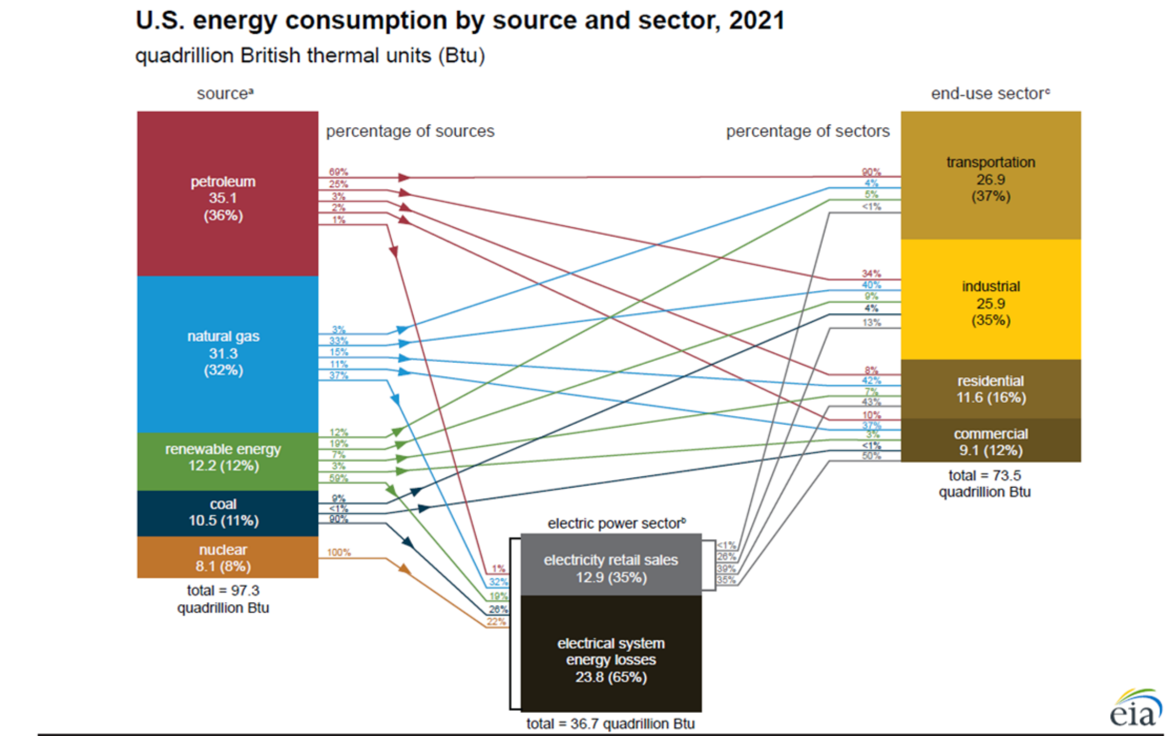
Beyond the unreliable characterization of some households as profligate and others as more careful users of residential electricity, these judgment-laden categories omit the larger context of energy use. Figure 4 is the 2021 EIA energy flows summary for the United States. Setting aside the net impact of imports and exports, virtually all energy use eventually benefits some US house-

Table 5: Demographics of "Hogs" and "Angels" Categories with Adjustments

	Low Income		White		Latinx	
PG&E	Angels	Hogs	Angels	Hogs	Angels	Hogs
Net Household Consumption	26%	28%	52%	57%	21%	20%
Net Per Capita Consumption	39%	23%	39%	69%	34%	8%
Gross Per Capita Consumption	45%	19%	33%	70%	37%	9%
+ Climate Zone	51%	21%	36%	67%	38%	8%
+ chld/senior, seasonal, WFH	49%	22%	35%	65%	39%	10%
+ elec appliances, building age	47%	24%	38%	61%	38%	16%
SCE	Angels	Hogs	Angels	Hogs	Angels	Hogs
Net Household Consumption	40%	30%	42%	55%	26%	25%
Net Per Capita Consumption	59%	18%	25%	68%	49%	15%
Gross Per Capita Consumption	62%	18%	18%	67%	52%	15%
+ Climate Zones	67%	17%	24%	67%	51%	14%
+ chld/senior, seasonal, WFH	65%	16%	25%	65%	51%	16%
+ elec appliances, building age	58%	18%	28%	64%	44%	16%
SDG&E	Angels	Hogs	Angels	Hogs	Angels	Hogs
Net Household Consumption	21%	21%	57%	72%	17%	7%
Net Per Capita Consumption	35%	13%	44%	79%	26%	7%
Gross Per Capita Consumption	47%	11%	35%	80%	40%	5%
+ Climate Zone	45%	10%	38%	74%	32%	7%
+ chld/senior, seasonal, WFH	42%	12%	39%	75%	31%	7%
+ elec appliances, building age	38%	13%	39%	74%	31%	5%

NOTE: This table presents the share of households in different demographic groups who fall into the Angels and Hogs categories (bottom 20 percentile and top 20 percentile of households) based on net household consumption (top line for each utility) and then after adjustments for unrelated factors. Low income is based on percent of poverty guideline. See appendix for details of variable constructions.

Figure 3

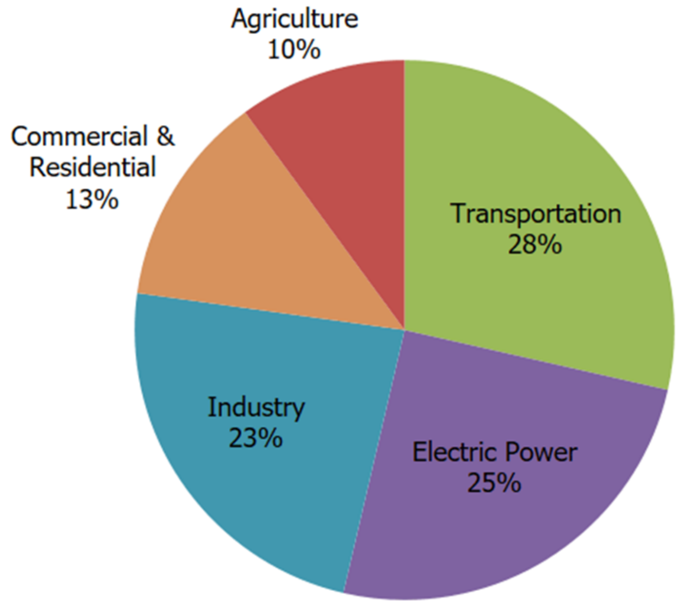


Source: https://www.eia.gov/energyexplained/us-energy-facts/

holds. Multiplying the share of primary energy that goes into electricity generation (36.7/97.3) by the share of electricity that is used by households (39%), implies that about 15% of US energy use is attributable to residential electricity consumption. In some parts of the country, ratemaking for residential natural gas also uses the rhetoric of more and less prudent consumption, and even some increasing-block pricing, but including residential natural gas still only raises the share of energy use covered by such quantity-based value judgments to 20% of US energy use.

The other 80% of energy use in the United States is still benefiting people who live in households, but it is largely exempt from suggestions that heavier energy users should shoulder higher prices or a larger share of unrelated and tangential costs. Prices for gasoline, air travel, energy-intensive production goods, housing, food, and all of the other goods and services that constitute the other 80% are set by market forces. For those products, the prudence of households that consume low or high quantities plays essentially no role. In fact, many such goods are sold with quantity discounts or additional benefits to customers who consume high quantities, such as through customer loyalty programs employed by airlines and other industries. Residential energy consumption seems to sit alone as an area of consumption for which some believe payment should be based on the ethics of high usage levels. As a result, households whose consumption

Figure 4: Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021



Source: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

preferences tilt more towards staying at home are harmed relative to those who choose to spend a higher share of their income on travel, dining out, and consuming goods and services. It is hard to come up with an equity-grounded argument for such asymmetric treatment. It is noteworthy, however, that residential electricity is one of a fairly small number of consumer goods for which consumption quantities are directly observable by a single delivering entity and its economic regulator, creating opportunity for such judgment-based, rather than cost-based, burden allocation.[14]

5.1 Energy and externalities

Justifications for penalizing heavy users typically focus not on energy consumption, but on the associated pollution externalities. The standard economic argument for raising price due to pollution externalities is hard to credit in California residential electricity with retail prices more

[14]A progressive consumption tax would have some similarities to the treatment of residential energy use, but it would apply to all, or nearly all, goods in the economy, so it would not single out one type of consumption. In addition, if the consumption tax law resembled US income taxes, it would have adjustments for number of members of the family, and perhaps for other factors that policymakers would view as not appropriate bases for taxation. The application of this approach only to residential energy consumption and without such adjustments makes it particularly problematic, especially due to the extremely high implicit tax imposed on residential electricity in California.

than double the full social marginal cost, which includes the cost of pollution externalities. Combining the information in figure 4 with the shares of greenhouse gases shown in figure 5 implies that residential electricity produces about 10% of US GHG emissions.[15]

Furthermore, the local pollution consequences of residential electricity consumption are likely to be an even smaller share of local pollution energy externalities. Based on the data in figure 4, residential electricity is responsible for a disproportionately high share of coal consumption compared to the share of GHG emissions, about 35% (90% x 39%), but a disproportionately low share of emissions from petroleum combustion, less than 1%, and about 14% of natural gas combustion. However, coal combustion, in electricity generation and industrial processes, tends to take place further away from populated areas than petroleum combustion, in transportation and home heating. More importantly, coal consumption is declining far more rapidly than petroleum and natural gas, suggesting that the non-GHG externalities from electricity are already a lower proportion than indicated by GHG totals in places like California, and will soon be throughout the US. Thus, if GHG and local pollution externalities are the concern, a focus on residential electricity consumption is particularly misplaced.

5.2 Hogs, angels and air travel—some further context

While the small share of energy usage and pollution externalities attributable to residential electricity suggests that other consumption is likely to be more consequential, comparison to air travel makes the point especially salient.

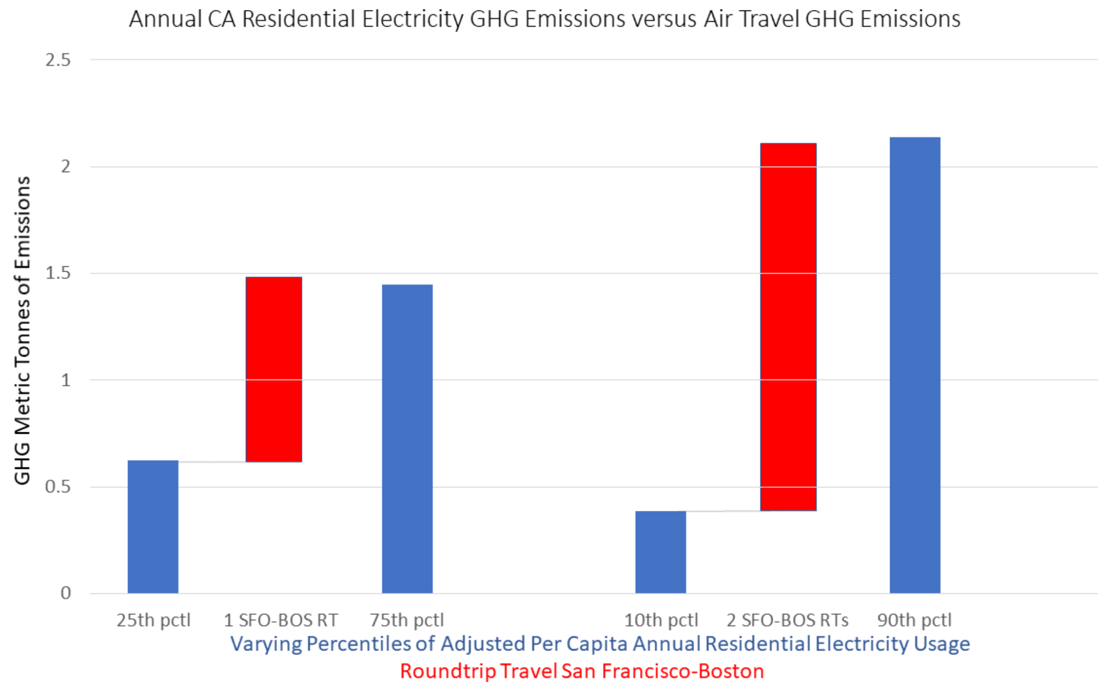
After controlling for number of occupants, distributed solar, and climate zone, the weighted-average difference between the 25th and 75th percentile gross per capita electricity consumption among the California IOUs is 2058 kWh/year and the weighted-average difference between 10th percentile and 90th percentile is 4372 kWh/year.[16] The marginal emissions rate from electricity generation in California is approximately 0.4 metric tons per MWh (Borenstein and Bushnell, 2022a), so the difference between the 25th and 75th percentiles of per capita electricity consumption is about 0.82 metric tons of GHG emissions and the difference between the 10th and 90th percentiles is about 1.72 metric tons of GHG emissions.

For comparison, in 2019, the US airline industry's peak year in passengers and load factor (as of 2023), the US domestic airline industry flew 763 billion passenger-miles using 12.18 billion

[15]From figure 4, 39% of electricity goes to residential use, and from figure 5, 25% of US GHG emissions are attributable to the electricity sector. $0.39 \cdot 0.25 \approx 0.1$.

[16]The 25th to the 75th percentile difference is 1835 kWh/year for SDG&E, 1968 kWh/year for SCE, and 2114 kWh/year (PG&E). The 10th percentile to 90th percentile difference is 3479 kWh/year for SDG&E, 4089 kWh/year for SCE and 4516 kWh/year for PG&E. I weight usage at each percentile level across the three utilities by their number of residential customers in 2019, according to the EIA-861.

Figure 5: Annual Residential Electricity GHG Emissions versus Air Travel GHG Emissions



gallons of fuel.[17] Air travel is a roughly constant returns to scale industry and load factors are quite resilient to economic fluctuations (apart from the very unusual circumstances of the COVID pandemic), implying that airlines quickly adjust the number of seats they offer when demand increases or decreases (Borenstein and Rose, 2014). Thus, the industry average fuel economy of about 62.6 ($= 763/12.18$) passenger-miles per gallon of jet fuel is a reasonable approximation of the marginal fuel use per passenger-mile. A round-trip flight from San Francisco to Boston is about 5400 miles, which thus burns about 86 gallons of jet fuel per passenger. One gallon of jet fuel produces approximately 0.01 metric tons of GHG emissions[18], so the SFO-BOS round-trip creates about 0.86 metric tons of emissions.

These calculations imply that the difference between the 25th percentile of per capita gross electricity consumption and the 75th percentile after controlling for three factors unrelated to efficiency or waste is about the same as the emissions from one SFO-BOS airline round-trip. The difference between the 10th and 90th percentile per capita consumption is about the same as two SFO-BOS round-trips, or one round trip between San Francisco and London.[19]

[17] See https://www.transtats.bts.gov/fuel.asp and https://web.mit.edu/airlinedata/www/TrafficCapacity.html

[18] https://www.eia.gov/environment/emissions/co2_vol_mass.php

[19] Interestingly, the fuel economy of long flights is about the same as medium-length flights. Though takeoff and climb to cruising altitude are particularly fuel intensive, long flight segments require carrying additional fuel, which

6 Conclusion

Utility regulators have extremely difficult, and generally thankless, jobs when it comes to rate setting. They need to figure out whether costs are reasonable, as well as the causal link between consumption and costs. They must adjudicate debates about fair rates of return and determine the cost-effectiveness of countless policy initiatives. Equity considerations are also critical in deciding how to allocate the revenue burden among different customers. Understandably, a group arguing that it would be more fair to apportion a greater share of the revenue collection to other customers is likely to suggest that their own class of customers are more prudent consumers. Unfortunately, in many cases, these assertions have been based on intuitively appealing, but empirically untested, theories. One of the most common of these is that residential customers who use more electricity are profligate, despite the fact that many factors unrelated to the prudence of usage are likely to be significant drivers of consumption quantity.

Of course, it is very difficult to measure wasteful use of electricity, or of any other good, and even difficult to find a widely accepted definition of wasteful use. In this paper, I have examined the question from the opposite starting point, investigating the factors that are generally agreed to be unrelated to prudence, but are still important determinants of usage. I have found that correcting for these factors greatly changes the picture of which customers one would first suspect of excessive consumption, that is, if one felt that judging differences in prudence of electricity consumption were an appropriate consideration in ratemaking at all. Customers who would be viewed as "energy hogs" based on net household consumption turn out to have a distribution that greatly overlaps with other customers when one incorporates factors such as the number of occupants in the house, gross consumption inclusive of distributed solar, differences in climate, demographics of the household, and appliances that the household is choosing to power with electricity rather than natural gas or gasoline. In fact, correcting only for occupants, distributed generation, and climate reduces by 59% to 82% the difference in average consumption between households that are above median usage and households that are below the median.

Such moral judgments of residential energy are even more suspect when placed in the larger context of economy-wide energy consumption or greenhouse gas emissions attributable to an individual or household. With residential electricity usage responsible for only 15% of US energy consumption, and only 10% of GHG emissions, it is clear that judging the prudence of energy usage or environmental impact from this metric is virtually certain to result in very high error rates. This is particularly true when such judgments are carried out without controlling for fundamental consumption drivers that are unrelated to the prudence of consumption.

increases weight per passenger. The two factors approximately offset one another.

Data Appendix

This appendix describes in detail the construction of the variables used in the analysis of household electricity consumption and presents the regressions on which figures1 and 2, and tables 1-5 are based.

6.1 Dataset Construction

The basis of the empirical analysis is the California Energy Commission's 2019 Residential Appliance Saturation Survey. The survey includes responses from slightly over 40,000 households, of which about 32,000 are customers of the investor-owned utilities and are individually metered. The variables used in the analysis and the details of their construction follow.

Annual net kWh usage: This variable is missing for about one-third of the IOU customers in the RASS. As part of the analysis in Borenstein, Fowlie and Sallee (2022), however, we were able to match customers to billing data from the IOUs and create a complete data set of annual net consumption. The details of the matching and approximation of annual consumption for customers who are in the billing data for only part of the year are presented in the data appendix to Borenstein, Fowlie and Sallee (2022).

Number of household occupants: The RASS reports separately the number of occupants under age 19, age 19-64, and 65 and over (A15). Each variable was set to zero if it was reported missing. Observations were dropped if the household reported more than nine occupants. The share of occupants who are children or seniors is the sum of the first and third variable divided by the total number of occupants.

Annual distributed solar PV generation: This variable is also taken from the analysis in Borenstein, Fowlie and Sallee (2022) and details of its creation can be found in that paper.

Climate Zone: This is the climate zone reported in the RASS for each household (CZT24).

Seasonal occupancy: This is based on the question in the RASS of whether or not the house is occupied year-round (A4). Seasonal occupancy is set to zero if it is reported to be occupied year-round or if the answer to this question is missing. It is set to one if it is reported to be occupied only seasonally.

Work from home: This is based on the question that asks whether a person in the home operated business or works from home (K5). I create a quasi-continuous variable that is equal to 5 if the respondent answers that someone works from home 0-10 hours per week, equal to 20 if the respondent answers that someone works from home 11-30 hours per week, and is set to 40 if the respondent answers that someone works from home more than 30 hours per week. The variable is set to zero if the works from home answer is missing.

Year that the home was built: This is based on the question in RASS that asked what year the residence was built (A6). A quasi-continuous variable was created that uses the average of the start and end year of each category. For homes built ”Before 1940” it was assumed that the home was built in 1930. A dummy variable for built year missing was created and set to one if the answer to this question is missing (and the year built for those observations is set to 1930, though that is just a normalization).

Electric appliances (space heating, hot water, clothes drying, stove, and oven): These are dummy variables based on the questions in RASS that asked what the primary source of fuel for each activity is (B2, D2, E5, F1). For all variables, if the answer was missing, it was assumed that electricity is not used for this activity.

Electric vehicle: This is a dummy variable based on the question in RASS asking whether anyone in the household drives an EV (A20).

Low household income: This is a dummy variable based on a calculation of reported income as a percentage of the 2019 national poverty guidelines for the number of occupants reported in the household. A household under three times the poverty guideline has a value of 1, otherwise 0. Unfortunately, the income report categories (N7) don't fall into clean multiples of the income in the national poverty guidelines, so categories were included if more than half of the range in the category put the household under three times the poverty level, given the number of occupants. For a small number of households, no income was reported; the RASS reports an imputed exact income for those households, which is used for those households.

White: This is a dummy variable based on the question in RASS that asks which ethnic groups are represented among the heads of household (N6). If there is only one head of household and that person self-reports as white or there are two heads of household and both self-report as white, it is set to 1, otherwise it is set to zero.

Latinx: This is a dummy variable based on the question in RASS that asks which ethnic groups are represented among the heads of household (N6). If either head of household #1 or head of household #2 self-reports as being "Hispanic/Latino", it is set to 1, otherwise it is set to zero.

Table 6: Regressions for PG&E

Dependent Variable	(1) $Net\ kWh$	(2) $\frac{Net\ kWh}{Occupants}$	(3) $\frac{Gross\ kWh}{Occupants}$	(4) $\frac{Gross\ kWh}{Occupants}$	(5) $\frac{Gross\ kWh}{Occupants}$	(6) $\frac{Gross\ kWh}{Occupants}$
Seasonal occupancy					-716.6*	-952.3**
					(420.6)	(394.3)
Share of occupants 19-64 years old					-948.9***	-928.7***
					(199.1)	(192.6)
Weekly hours worked from home					16.30*	11.31
					(8.431)	(8.595)
Year dwelling built						1.448
						(3.373)
Year dwelling built missing						2.086
						(284.3)
Electric vehicle						1,267***
						(300.7)
Electric clothes dryer						271.7**
						(133.1)
Electric stove						-452.1***
						(170.2)
Electric oven						633.8***
						(163.2)
Electric hot water						725.1***
						(212.2)
Electric space heat						120.6
						(177.7)
2-Climate zone				-568.3	-570.7	-654.8
				(542.9)	(463.9)	(533.3)
3-Climate zone				-1,256**	-1,216***	-1,145**
				(538.5)	(458.8)	(531.3)
4-Climate zone				-814.7	-744.2	-783.0
				(542.6)	(463.4)	(532.7)
5-Climate zone				-997.5*	-994.6*	-891.5
				(601.4)	(536.7)	(591.3)
11-Climate zone				454.7	415.9	428.5
				(608.9)	(540.8)	(595.7)
12-Climate zone				270.4	228.0	170.3
				(558.2)	(484.3)	(548.0)
13-Climate zone				678.8	632.5	791.6
				(617.1)	(549.9)	(614.7)
16-Climate zone				-12.73	16.30	-309.1
				(578.4)	(501.3)	(538.6)
Constant	5,493***	2,485***	2,933***	3,332***	3,816***	553.7
	(124.3)	(62.21)	(73.63)	(531.8)	(480.0)	(6,625)
Observations	12,854	12,854	12,854	12,854	12,854	12,854
R-squared	0.000	0.000	0.000	0.092	0.116	0.155

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7: Regressions for SCE

Dependent Variable	(1) $Net\ kWh$	(2) $\frac{Net\ kWh}{Occupants}$	(3) $\frac{Gross\ kWh}{Occupants}$	(4) $\frac{Gross\ kWh}{Occupants}$	(5) $\frac{Gross\ kWh}{Occupants}$	(6) $\frac{Gross\ kWh}{Occupants}$
Seasonal occupancy					-958.5***	-956.9***
					(320.5)	(320.0)
Share of occupants 19-64 years old					-300.5*	-311.8*
					(174.3)	(168.6)
Weekly hours worked from home					19.83**	16.52**
					(7.866)	(8.022)
Year dwelling built						1.684
						(2.509)
Year dwelling built missing						52.83
						(351.4)
Electric vehicle						1,897***
						(363.1)
Electric clothes dryer						313.4**
						(142.1)
Electric stove						-82.29
						(145.5)
Electric oven						364.7***
						(130.6)
Electric hot water						670.9***
						(231.8)
Electric space heat						-346.0**
						(141.5)
8-Climate zone				-449.0***	-432.5***	-315.8**
				(161.7)	(164.1)	(160.2)
9-Climate zone				-107.9	-102.7	9.298
				(164.8)	(164.6)	(164.3)
10-Climate zone				509.0**	540.7**	654.4***
				(224.9)	(228.6)	(242.0)
13-Climate zone				1,118***	1,121***	1,232***
				(380.5)	(368.2)	(356.6)
14-Climate zone				771.4**	821.1**	1,007***
				(371.4)	(373.0)	(372.8)
15-Climate zone				2,445***	2,660***	2,622***
				(275.5)	(302.2)	(309.9)
16-Climate zone				561.7	716.7*	718.9*
				(423.8)	(406.3)	(401.5)
Constant	5,943***	2,552***	2,790***	2,640***	2,735***	-882.4
	(98.64)	(55.40)	(63.05)	(133.2)	(151.6)	(4,900)
Observations	13,073	13,073	13,073	13,073	13,073	13,073
R-squared	0.000	0.000	0.000	0.058	0.068	0.112

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Regressions for SDG&E

Dependent Variable	(1) $Net\ kWh$	(2) $\frac{Net\ kWh}{Occupants}$	(3) $\frac{Gross\ kWh}{Occupants}$	(4) $\frac{Gross\ kWh}{Occupants}$	(5) $\frac{Gross\ kWh}{Occupants}$	(6) $\frac{Gross\ kWh}{Occupants}$
Seasonal occupancy					-261.3	-285.6
					(777.9)	(679.2)
Share of occupants 19-64 years old					-156.3	-303.8
					(248.1)	(251.4)
Weekly hours worked from home					26.35**	14.82
					(10.99)	(10.86)
Year dwelling built						-0.383
						(4.251)
Year dwelling built missing						-259.0
						(291.6)
Electric vehicle						1,580***
						(465.6)
Electric clothes dryer						443.3*
						(239.6)
Electric stove						-582.6***
						(171.0)
Electric oven						297.2
						(215.3)
Electric hot water						188.3
						(198.9)
Electric space heat						-69.10
						(156.0)
7-Climate zone				-537.4*	-428.0*	-159.4
				(274.2)	(256.0)	(291.6)
8-Climate zone				23.40	-168.5	275.2
				(467.4)	(488.3)	(494.1)
10-Climate zone				278.7	332.1	596.2*
				(350.6)	(336.4)	(352.6)
14-Climate zone				655.9	784.2	1,265**
				(615.4)	(627.8)	(527.0)
15-Climate zone				1,757*	1,977*	1,816
				(1,053)	(1,056)	(1,142)
Constant	4,266***	1,921***	2,416***	2,685***	2,581***	3,087
	(137.5)	(80.69)	(89.07)	(258.1)	(308.9)	(8,387)
Observations	4,336	4,336	4,336	4,336	4,336	4,336
R-squared	0.000	0.000	0.000	0.039	0.064	0.127

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

References

ABC News. 26 March 2001. "Calif. Power Regulator Calls for Rate Boost." https://abcnews.go.com/US/story?id=93718page=1.

Borenstein, Severin. 20 June 2023. "Electricity Pricing and the Social Cost of Carbon." Energy Institute at Haas blog, U.C. Berkeley, https://energyathaas.wordpress.com/2019/07/08/rethinking–demand–charges/.

Borenstein, Severin. 2012. "The Redistributional Impact of Non-Linear Electricity Pricing." American Economic Journal: Economic Policy, 4(3): 56–90.

Borenstein, Severin. 2013. "Effective and equitable adoption of opt-in residential dynamic electricity pricing." Review of Industrial Organization, 42: 127–160.

Borenstein, Severin. 2016. "The economics of fixed cost recovery by utilities." The Electricity Journal, 29(7): 5–12.

Borenstein, Severin. 8 July 2019. "Are Demand Charges Fair?" Energy Institute at Haas blog, U.C. Berkeley, https://energyathaas.wordpress.com/2019/07/08/rethinking–demand–charges/.

Borenstein, Severin, and James B Bushnell. 2022a. "Do two electricity pricing wrongs make a right? Cost recovery, externalities, and efficiency." American Economic Journal: Economic Policy, 14(4): 80–110.

Borenstein, Severin, and James B Bushnell. 2022b. "Headwinds and tailwinds: Implications of inefficient retail energy pricing for Energy substitution." Environmental and Energy Policy and the Economy, 3(1): 37–70.

Borenstein, Severin, and Nancy L Rose. 2014. "How airline markets work… or do they? Regulatory reform in the airline industry." In Economic regulation and its reform: What have we learned?. 63–135. University of Chicago Press.

Borenstein, Severin, Meredith Fowlie, and James Sallee. 2021. "Designing electricity rates for an equitable energy transition." Energy Institute at Haas Working Paper, 314.

Borenstein, Severin, Meredith Fowlie, and James Sallee. 2022. "Paying for Electricity in California: How Residential Rate Design Impacts Equity and Electrification." Energy Institute at Haas Working Paper, 330.

Bustamante, Claudia, Stephen Bird, Lisa Legault, and Susan E Powers. 2023. "Energy Hogs and Misers: Magnitude and Variability of Individuals' Household Electricity Consumption." Sustainability, 15(5): 4171.

CPUC. 2021. "Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity Issues." California Public Utility Commission Working Paper.

Elmallah, Salma, Anna M Brockway, and Duncan Callaway. 2022. "Can distribution grid infrastructure accommodate residential electrification and electric vehicle adoption in Northern California?" Environmental Research: Infrastructure and Sustainability, 2(4): 045005.

Ito, Koichiro. 2014. "Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing." American Economic Review, 104(2): 537–63.

JDSupra. 2023. "PG&E and SCE's Wildfire Mitigation Plans Detail More than $23 billion in Expenditures through 2025." https://www.jdsupra.com/legalnews/pg-e-and-sce-s-wildfire-mitigation-2999883/.

Kahn, Alfred Edward. 1988. The economics of regulation: principles and institutions. Vol. 1, MIT Press.