Assessing Equity in TOU: How Low-Income Customers Fare on Time of Use Rates

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ABSTRACT

Utilities are finding that alternative rates (such as time of use [TOU] supply rates and time-varying demand rates) can motivate many customers to change their energy use behaviors to better align with grid needs, ultimately paving the way for increased deployment of renewables and distributed energy resources (DERS) and decreasing the need for peaker plants, traditional distribution upgrades, and the like. Despite these benefits, some electricity providers and customer advocates are concerned that alternative rates may exacerbate the existing economic hardship of low-income customers. But is this actually the case? Research suggests that low-income customers typically pay less under TOU rates with little to no changes in their occupant behavior, especially considering volumetric rate designs can result in overpayment from low-income customers due to their flatter load shapes. Despite the potential for bill savings, our research demonstrates that low-income customers are significantly less aware of and, perhaps more importantly, significantly less interested in alternative rates than moderate- to high-income customers. Given that alternative rates pose a considerable equity enhancing and bill reduction opportunity, how do we get more low-income customers on board? This paper presents findings spanning the nation from several major studies on alternative rates and demonstrates how low-income customers have fared on a variety of metrics across the various alternative rates we have evaluated, including such topics as: awareness, interest, economic effects, bill impacts, and behavior change. This paper concludes with evidence-based recommendations for improving low-income participation in alternative rate offerings.

Introduction

As electric utilities shift from the broader strategy of energy efficiency to more precise goals of flexible demand response (that is, smoothing hourly demand so that demand does not exceed grid capacity in a given moment in time), utilities are increasingly looking to customer pricing mechanisms as a means of "shaving the peak" and alleviating issues associated with intermittent distributed generation. Utilities have experimented with a myriad of pricing mechanisms to either reduce peak demand and/or shift demand from peak hours to off-peak hours. Broadly, these pricing strategies use a "carrot and/or stick" approach to influencing hourly customer demand, where customers are either financially penalized for using electricity during certain peak times (e.g., "surge" pricing), rewarded for successfully reducing their use during peak timeframes (e.g., bill credits), and/or incented to concentrate their use during off-peak hours (e.g., discounted pricing).

These monetary-based behavior change strategies can be either event- or rate-based (or some combination of the two). Event-based strategies are isolated in nature: the pricing

mechanism event is announced shortly before the event is set to take place and is called as a direct reaction to grid forecasts that suggest that demand may exceed supply during an upcoming timeframe (commonly, on particularly hot summer days when air conditioning use is predicted to contribute excessively high demand than what is otherwise expected during that timeframe). Rate-based pricing mechanisms build the carrots and sticks into the electricity rate itself, where an electricity pricing plan uses time-based pricing to encourage demand response throughout the year (be it afternoons during summer months, weekdays, all days of the year, etc.).[1]

This paper focuses on rate-based pricing mechanisms in the residential sector. These "alternative rates" come in many forms, but essentially share one thing in common: time-variable electricity pricing. Research conducted by Opinion Dynamics for the Smart Energy Consumer Collaborative in 2019 explored some of the most common types of alternative rates employed in residential markets across the U.S. to date. Table 1 outlines these alternative rates, including brief explanations of the rates and the name commonly attributed to each.

Table 1. Common alternative rates

Rate Name	Description*
Time-of-Use	The kWh price of electricity changes throughout the day, where different fixed prices are applied to specified blocks of hours throughout the day - there are typically two types of blocks of time "peak" (where electricity costs more) and "off peak" (electricity costs less), but some providers offer plans with additional blocks (like "super peak" and "super off peak").
Electric Vehicle Rate	A special time-of-use rate for electric vehicle drivers, where nighttime kWh prices are lowered for charging electric vehicles overnight.
Real Time Pricing	The kWh price of electricity is constantly changing every day of the year, with kWh prices typically changing on an hourly basis.
Variable Peak Pricing	A combination of real time pricing and time-of-use, where the peak and off-peak time periods are specified, but the peak kWh price is constantly changing every day of the year.
Demand Pricing	There are two common approaches: 1) The kWh price of electricity is determined by the maximum amount of electricity that a customer uses in their highest 15-minute interval of electric use during their billing cycle (customers with a lower maximum electric usage period pay a lower kWh price than customers with a higher maximum use period). 2) In addition to paying for kWh (cumulative energy use), customers pay for their measured demand (which may have a time-of-use component, where peak periods are subject to higher demand rates).

* Note that rate descriptions are provided for illustration purposes only and are not intended to be exhaustive descriptions of the rate. Specifics for a given rate type can vary widely across utilities.

[1] Granted, event-based pricing mechanisms are often tied to a rate. However, we use this classification system to distinguish between event- and non-event-based pricing mechanisms.

Alternative rates – such as TOU – have successfully resulted in demand reduction, albeit load impacts vary by jurisdiction (Braithwait, Hansen, and Clark 2017; George et al. 2017a; George et al. 2017b; Lessem et al. 2017; Opinion Dynamics 2018; Opinion Dynamics 2014). Despite successful demand reduction, substantial proportions of customers may experience increased bills. For example, a study the authors contributed to (George et al. 2017a) found that customers had higher electricity bills on average under TOU rates in summer months (relative to standard tiered rates that preceded TOU rates), even though observable demand reductions were achieved. However, as exemplified in the second piece of that study (George et al. 2017b), customers with TOU rates from summer peaking electric utilities are likely to experience comparatively lower bills in winter months (relative to standard tiered rates). Thus, for single-season peaking utilities, TOU pricing poses a tradeoff: although customers may pay more in peaking months, they make it up with the natural bill savings achieved in off-peak months. Even if this outcome is a net positive for the customer (in that they accumulate greater savings in off-peak months than losses incurred in peaking months), low-income customers may not have the means to afford the temporarily higher-than-normal bills during peak months. And dual-peaking electric utilities clearly constitute an even greater economic hardship risk for their low-income customers, as there is no "makeup period."

Concerns about inequitable impacts on low-income customers is not limited to TOU rates, as any time-based alternative rate could theoretically harm the economic wellbeing of low-income customers. For example, low-income customers may be least likely to understand the rate change or rate components, may lack the financial means to invest in technologies that assist in load shifting/reduction, and may have personal situations (such as working night shifts or having retired persons living in the home) that force them to concentrate their electricity use during the most expensive hours. Due to these anecdotal theories, some electricity providers and customer advocacy groups are concerned that alternative rates may exacerbate the existing economic hardship of low-income customers. But is this actually the case? The subsequent section explores findings from several studies on low-income customers and alternative rates, ultimately exposing the complex relationship between the two.

Findings

Awareness

Research conducted by Opinion Dynamics for the Smart Energy Consumer Collaborative (SECC) in 2019 explored consumer awareness of various electricity rates, using a nationally representative sample of 1,138 of residential consumers. The study found that American consumers are moderately aware of alternative rates (Smart Energy Consumer Collaborative and Opinion Dynamics 2019), although additional analysis conducted for this paper found that surveyed low-income households (those reporting household incomes of less than $25,000) tended to be less aware. Figure 1 shows the proportion of low-income and non-low-income consumers that were aware of each rate covered in the survey (plus two event-based pricing mechanisms). As seen in the table, awareness of traditional rate plans (flat, tiered) were similar across income categories, but low-income customers were significantly ($p<.05$; z-test) less aware of many alternative rate plans. Further, low-income customers were nearly twice as likely to be unaware of any of the rates or event-based pricing mechanisms included in the survey.

Interestingly, awareness of one's current rate plan was not differentiated by income status: 64% of low-income consumers claimed to know their current rate plan type, compared to 68% of non-low-income households (a statistically non-significant difference).

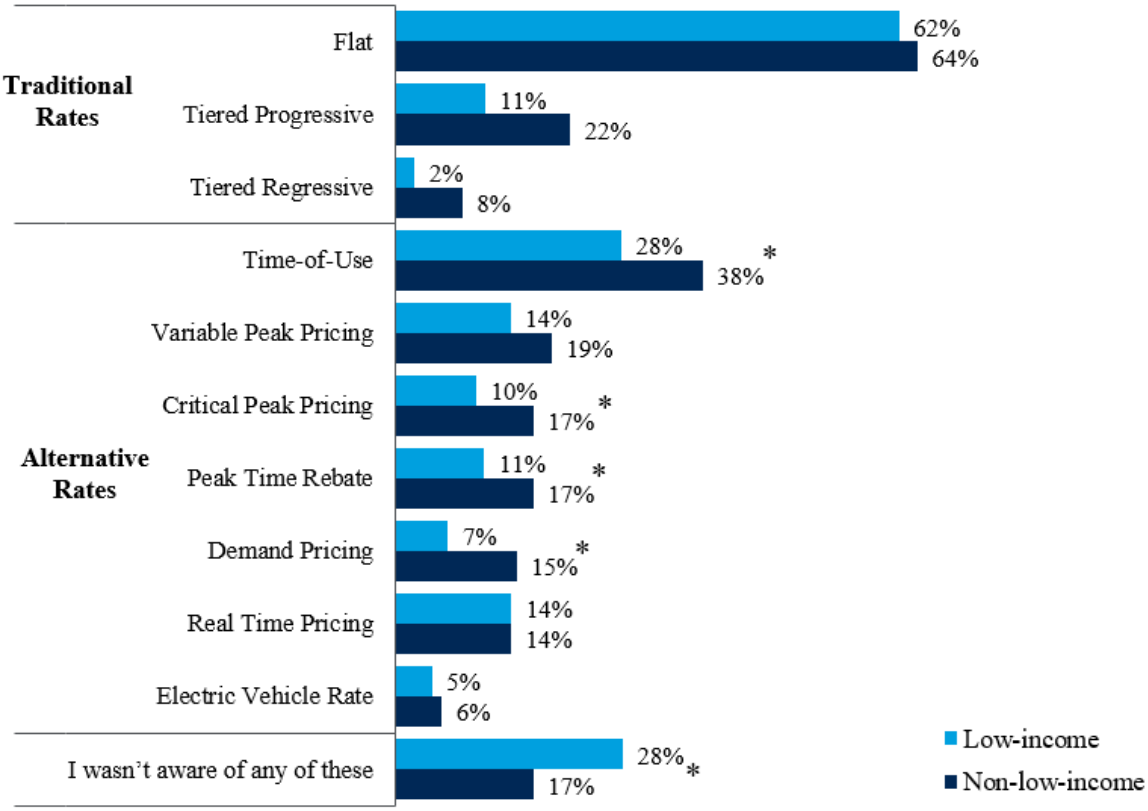

Figure 1. Awareness of alternative rates and event-based pricing mechanisms, by low-income. Asterisks (*) denotes significant differences ($p<.05$) from z-tests.

Our research above demonstrates overall American awareness of alternative rates, which is perhaps impressively high considering that less than 5% of residential households are on an alternative rate.[2] So what about consumers that are currently enrolled in an alternative rate plan? Opinion Dynamics recently conducted evaluations of two alternative rate pilot programs that defaulted residential customers onto two unique TOU rates: one in California that had TOU kWh pricing, the other in New York with TOU demand [kW] pricing. As seen in Table 2, despite significant direct-to-customer outreach campaigns from either utility, low-income customers were significantly ($p<.05$; z-test) less aware that they had been automatically transitioned to an alternative rate than non-low-income customers.[3] These real-world examples corroborate findings from our SECC study, suggesting that low-income customers may be less aware of TOU rates even when they are enrolled in them.

[2] The authors used 2017 U.S. Energy Information Administration (EIA) data to generate these estimates. Consumers on alternative rates refer to consumers enrolled in rates or programs classified as "Dynamic Pricing" in EIA data, which includes time-of-use, real-time pricing, variable peak pricing, critical peak pricing and critical peak rebates.
[3] Both utilities defined low-income customers as those enrolled in their low-income discount programs. Both sets of results come from a "welcome survey" administered in the month following the transition to the new rate.

Table 2. Awareness of transition to new rate, by low-income program participation status

	Low-income	Non-low-income
California Utility - kWh TOU*	64%	69%
New York Utility - kW TOU*	51%	63%

Asterisks (*) denotes significant differences ($p<.05$) from z-tests.

Preference

Opinion Dynamics' 2019 SECC rates study used a choice-based conjoint study to explore consumer preference for some of the alternative rate plans shown in Table 1**Error! Reference source not found.**.[4] The conjoint study found that preference for alternative rates (namely, TOU) was fairly high across a variety of demographic segments; overall, 62% of American residential customers preferred an "ideal" TOU rate plan (a simple TOU rate with two tiers [peak and off-peak] with no demand charges that includes a $50 bill credit sign-on bonus) over a standard rate (where $/kWh prices do not vary throughout the day). However, low-income respondents demonstrated some of the lowest preference for alternative rates out of all demographics tested. Nonetheless, low-income interest in alternative rates was fairly high, with 56% of low-income respondents preferring this ideal TOU rate (over a standard rate) compared to 64% of non-low-income respondents (Smart Energy Consumer Collaborative and Opinion Dynamics 2019).

Additional analysis of the conjoint data for this paper found a striking difference as to what constitutes an "ideal" rate plan for low-income customers. One attribute tested in the conjoint study was a sign-on benefit, where respondents were able to choose from rates that had one of the following sign-on benefits: a one-time $50 bill credit, bill protection/price guarantee for one year, a rate comparison that shows what they might pay on the new rate plan compared to their old plan, and no sign-on benefit. Although the sign-on benefit was one of the least influential elements on which rate respondents chose, low-income customers were significantly more drawn to the one-time $50 bill credit; simulations revealed that low-income respondents' top nine most ideal rate plan configurations had a $50 bill credit, with the 10th most preferred rate plan configuration finally including a price guarantee. Conversely, non-low-income respondents' *second* most preferred rate plan configuration included a price guarantee (the bill credit only had a slight edge over the price guarantee for non-low-income customers). Granted, as shown in subsequent sections, low-income customers are likely to save money over the course of a year on a TOU rate (compared to a flat volumetric rate), but low-income respondents were not aware of this "winning potential" when taking the survey. This finding suggests that many low-income customers prefer the immediate benefit of a one-time bill credit, even though bill protection is ostensibly a more responsible choice for a consumer that is unaware how their bill may change on a TOU rate (as it insures their financial interests in the long run).

[4] Conjoint is a unique survey methodology that asks respondents to select which option (in this case, which rate plan) they would choose if they were limited to the options on their screen. This "discrete choice scenario" is repeated several times for each respondent: on each screen, respondents chose from one of three unique alternative rate plan configurations or a standard rate plan (where electricity prices are consistent regardless of time of day). See the cited report (Smart Energy Consumer Collaborative and Opinion Dynamics 2019) for further details on the conjoint methodology.

Shifting from forecasted to observed preference, the following results stem from our evaluation of a recent residential default TOU pilot conducted by Pacific Gas and Electric Company (PG&E). Figure 2 shows results from four tracking surveys administered before, during, and after the one year TOU pilot. As seen in the figure, preference for TOU rates grew considerably for both low-income and non-low-income customers once they had some experience on the new rate (readily exceeding preference for the tiered rate they had prior to the TOU pilot), with preference for TOU among either income group reaching an all-time high by the end of the first year of the pilot. Further, the results reveal that preference for TOU rates is similar regardless of income status, reinforcing that experience may help close any income-based preference gaps. Despite witnessing increased preference for TOU rates, "don't know" remained the most popular answer for both income groups throughout the pilot.

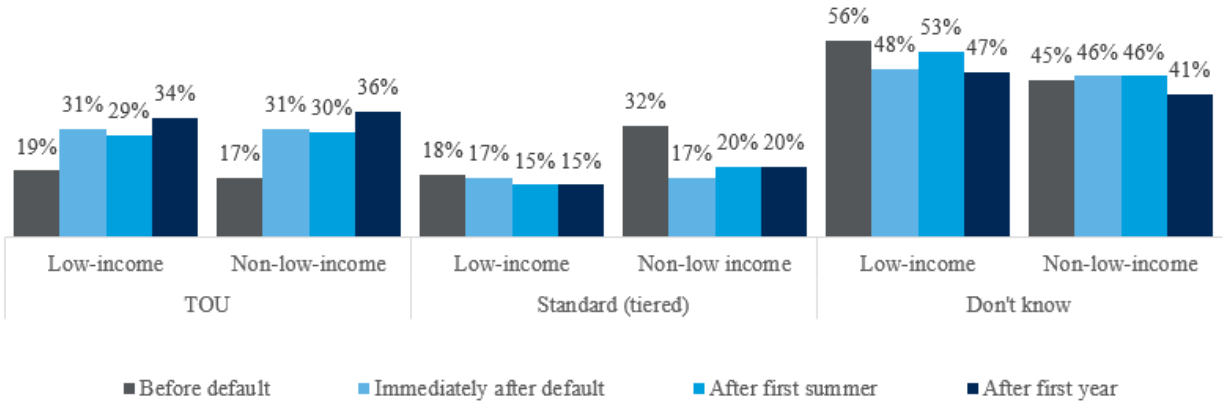

Figure 2. Preferred rate plan, by income status.
Note that the figure excludes "other" responses, which ranged from 3% to 7%.

Experience

Given that awareness, understanding, and preference tends to be lower among low-income customers – how do low-income customers fare on alternative rates? The following case studies explore the low-income experience on TOU rates in California.

Case study: PG&E TOU Default Pilot. In 2018-2019 PG&E conducted a default TOU pilot, where approximately 150,000 residential customers were automatically transitioned onto a TOU rate (Xavier and Folks 2018). The authors surveyed multiple waves of pilot participants, between ~2,000 to ~3,000 participants per survey. Analysis of billing data demonstrates the strong relationship between income and bill impacts from TOU rates. If their load shapes were to remain unchanged (that is – no behavior change, assuming similar weather patterns to the previous year), the majority (75%) of PG&E's low-income customers defaulted onto a TOU rate were predicted to benefit from TOU rates (compared to standard tiered rates) in that they would

save more than $5 in total energy costs over the course of the year (Table 3).[5] One-fifth (20%) were predicted to have a net neutral outcome (+/- $5 or less), and only 5% were predicted to achieve "non-benefiter" status (where they would experience a cumulative bill increase of more than $5).[6] Conversely, nearly half (49%) of non-low-income customers were predicted to achieve non-benefiter status, over two-fifths (44%) were expected to have neutral bill impacts, and only 7% would naturally benefit from the TOU rate.[7]

Table 3. Predicted bill impact, by low-income program participation status

	Predicted Bill Impact		
	Benefiter	Neutral	Non-benefiter
Low-income	75%	20%	5%
Non-low-income	7%	44%	49%

At the end of the first year of the rate, achieved bill impacts far exceeded forecasts: nine out of ten (90%) low-income customers benefited from the TOU rate (Table 4). Further, non-low-income customers dramatically improved from modeled outcomes, going from 7% predicted to benefit (Table 3) to 59% saving money on the TOU rate (Table 4).

Table 4. Actual bill impact, by low-income program participation status

	Achieved Bill Impact		
	Benefiter	Neutral	Non-benefiter
Low-income	90%	4%	6%
Non-low-income	59%	9%	32%

Since predicted bill impact assumed no behavior change, improvements from predicted to achieved likely point to load shifting (especially among non-low-income customers). Survey results corroborate this, with about half of low-income (46%) and non-low-income (50%) customers reporting they reduced or shifted their use over the course of the one-year pilot. However, income status was a significant predictor of the types of load shifting behaviors undertaken, with low-income customers being more likely to report turning off home office or entertainment equipment and non-low-income customers reporting avoiding using larger appliances at higher rates (Figure 3).

[5] Low-income customers are defined as those enrolled in the California Alternate Rates for Energy/Family Electric Rate Assistance (CARE/FERA) programs. Recent research found that 90% of eligible customers participate in CARE (Opinion Dynamics and DNV GL 2019). Note that CARE/FERA customers residing in hot climate zones were excluded from the default pilot. As such, the analysis presented here excludes non-CARE/FERA customers from hot climate zones for comparison validity purposes.

[6] Note that customers received bill protection, where they received a bill credit at the end of the first year on the TOU rate if they experienced a net loss (exceeding $5 for low-income customers, exceeding $10 for non-low-income customers).

[7] Note that non-low-income customer bill impacts used +/- $10 as the threshold for benefiter/neutral/non-benefiter status.

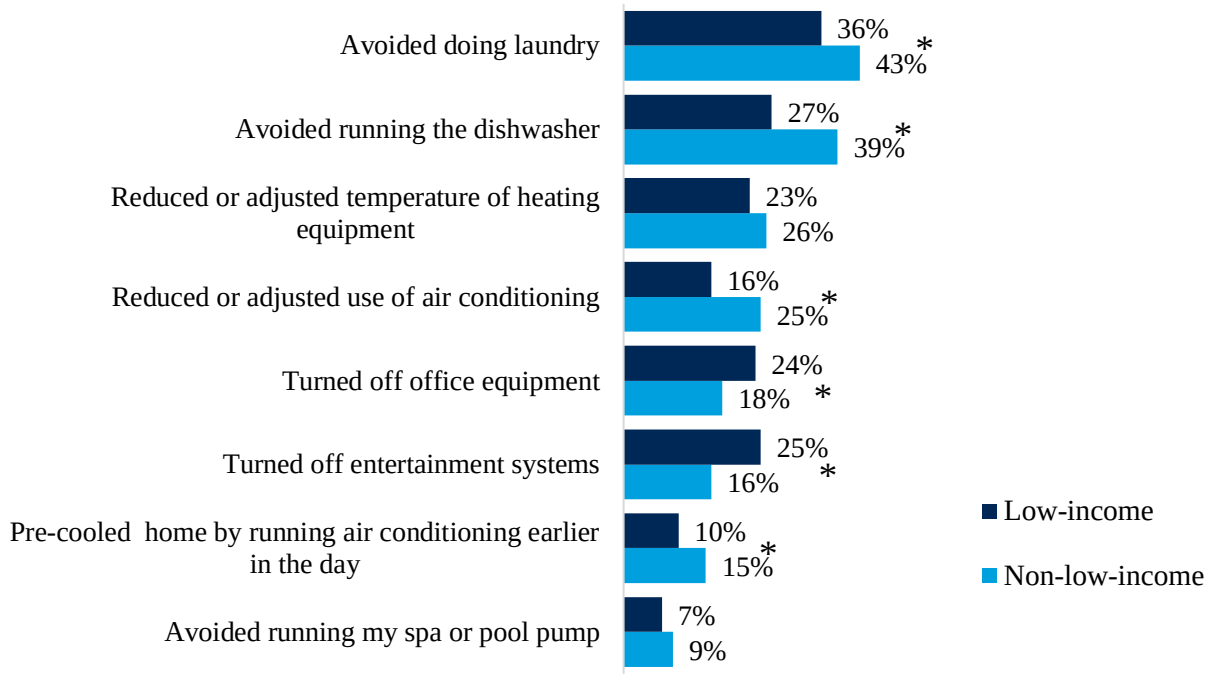

Figure 3. Actions taken to reduce or shift household electricity usage, by income status.
Asterisks (*) denotes significant differences ($p<.05$) from z-tests.
Note that the results in the figure accounts for 'not applicable – do not have equipment' responses, which ranged from 1% (non-low-income washer/dryer) to 38% (low-income pool pump). These respondents were included when conducting these calculations, since 'not applicable' responses may be underreported and so that results demonstrate overall frequency of load shifting behaviors among the target population.

The authors hypothesize that income-based differences in the types of reported load-shifting behaviors may be more a function of income-based disparities in the types of technologies found in the home, as opposed to educational or preference differences. Sure enough, low-income respondents were significantly ($p<.05$; z-test) more likely to report that the load shifting behavior did not apply to them because they did not have the associated technology in their home (other than pool pumps and entertainment systems, which received similar levels of "not applicable" responses between either income group).

Even though low-income customers may have fewer energy intensive items in their home, do they nonetheless face greater barriers to shifting whatever load they do have? Participant survey results suggest that barriers to effective load shifting are not uniquely tied to household income. In fact, both income groups tended to report few barriers to reducing or shifting their use (Figure 4). The results suggest that most customers – regardless of income – did not tend to face any significant barriers to reducing or shifting their use; all barriers were reported by less than one-third of respondents. Instead, customers most commonly reported 'non-barriers' such as "I've done all I can do" or "my household already uses very little electricity." And although low-income customers were significantly more likely to report children or disabled persons in their household as barriers, these were only mentioned by a minority of respondents and are arguably offset by non-low-income customers' greater likelihood of citing working from home as a barrier. Focus groups with customers defaulted onto the TOU rate provide additional

evidence that low-income customers did not face unique barriers to shifting energy usage: low-income and non-low-income customers alike discussed similar barriers to shifting load (e.g., customers who worked during the day had issues with shifting cooking and watching TV, regardless of income status). Further, non-low-income focus group participants expressed the greatest dismay at the potential for needing to shift their load, demonstrating greater concern for how it may impact their quality of life (e.g.: comfort, hassles) than low-income participants.

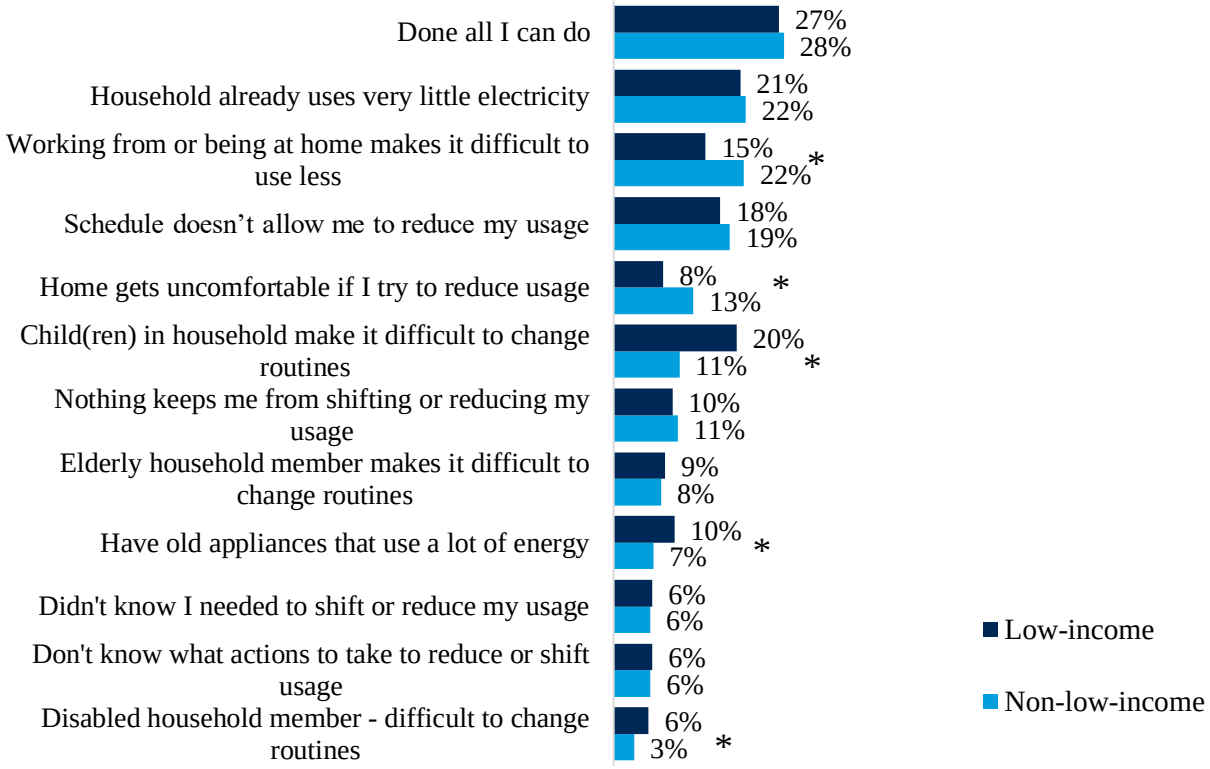

Figure 4. Reported barriers to reducing or shifting household electricity usage, by income status. Asterisks (*) denotes significant differences ($p<.05$) from z-tests.

These findings suggest that households shift the load that they have (e.g., lower rates of avoiding use of laundry machines or dishwashers among low-income customers is because these customers are less likely to have these appliances in the first place, as opposed to income-based load shifting inability). One of the primary arguments against defaulting low-income customers onto TOU rates is that their schedules or personal situations do not allow them to shift or reduce their use. This pilot suggests that not only is this not the case, but their natural load shape (e.g., fewer appliances in the home) tends to result in bill savings even without load shifting.

Customer satisfaction offers another key performance indicator of the low-income experience on TOU rates. As seen in Figure 5, low-income customers were significantly ($p<.05$; t-test) more satisfied than non-low-income customers with the TOU rate – as well as their utility – over the course of the pilot. Although low-income customers demonstrated a drop in rate satisfaction at the onset of the pilot, satisfaction with the rate rebounded to similar levels by the end of the first year on the TOU rate. This finding suggests that initial growing pains of the rate can smooth over once low-income customers have some time to adapt to the new rate.

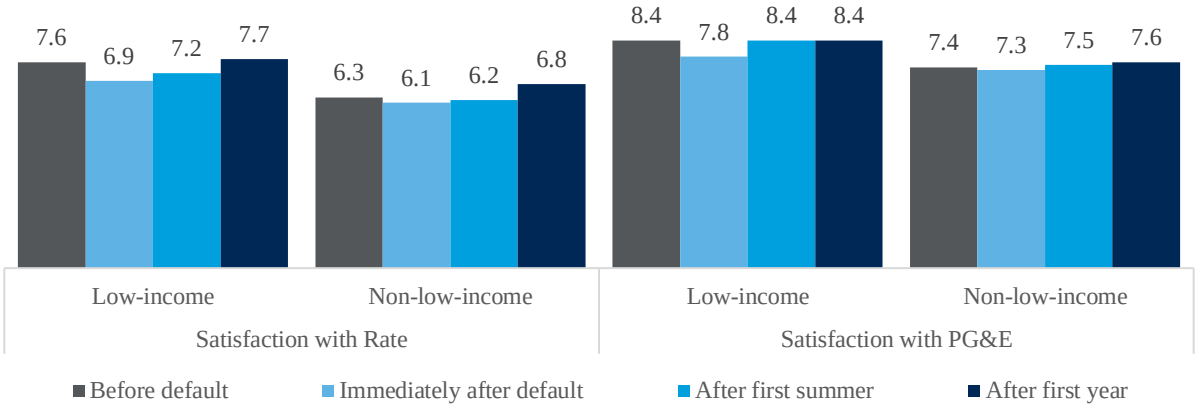

Figure 5. Satisfaction with rate plan and PG&E, by income status.
Reported values represent mean satisfaction on a 10-point scale where 1 means "extremely dissatisfied" and 10 means "extremely satisfied." Income-based differences for each period/item are statistically significant ($p<.05$) in t-tests.

As this case study demonstrates, the vast majority of low-income customers can save money on TOU rates; most of which need not change their behavior to do so. Comparisons of reported load shifting behaviors and bill impacts corroborate this assertation, as over half (53%) of low income customers that ultimately saved money after their first year on the rate did *not* report adjusting their behavior in response to the rate. However, this year-end net benefit may require paying more in summer months and then making the losses back in winter months. Although most non-low-income households may be able to financially accommodate this seasonal billing fluctuation, there is a possibility that certain low-income households could struggle to afford the increased payments during summer months (regardless of the net benefit achieved by the end of a year on the TOU rate). The next case study explores whether this seasonal billing phenomenon materially impacts the economic livelihood of low-income households on TOU rates.

Case study: California Statewide Opt-in Time-of-Use Pricing Pilot. Beginning in the summer of 2016, California's three largest investor owned electric utilities (or, IOUs: PG&E, Southern California Edison [SCE], and San Diego Gas and Electric [SDG&E]) conducted opt-in pilots of residential TOU electric rate designs. Each IOU piloted two or three unique rates; each pilot rate had unique peak pricing and timing. The authors contributed to the evaluation of these pilots, specifically focusing on whether the pilots caused unreasonable hardship for economically vulnerable households or customers with seniors in the household. Since bill impacts alone cannot expose the more sociological issue of whether TOU rates cause economic hardship, we relied on two customer surveys to answer this research question (one survey was conducted at the end of the first summer and another at the end of the first full year on the TOU rates). Drawing from a randomized controlled trial (RCT) study of over 55,000 California households that were assigned to either a TOU or standard rate, the research team designed a battery of survey questions (including the Consumer Financial Protection Bureau's Financial Well-Being Scale) to assess specific aspects of economic well-being, which ultimately culminated in an

index measuring degree of economic hardship experienced since the pilot began.[8] Thus, the underlying purpose of this research was to answer: *if vulnerable populations experience higher electricity bills under TOU rates, does this bill increase significantly worsen their economic well-being, or does the increased bill have no substantial effect on their economic livelihood?*

Structural bill impact results demonstrated that PG&E and SCE households on a TOU rate paid an average of $5 to $40 more a month during the summer than what they would have paid on a standard rate (with low-income customers tending to experience smaller increases than non-low-income customers) and that most customers were only able to offset a small percentage of the summer bill increase via behavior change.[9] Conversely, SDG&E customers experienced extremely minimal structural impacts, with considerable numbers of customers offsetting small structural bill increases via behavior change. Accordingly, SDG&E customers commonly had slightly lower bills during the summer period than they would have had on a standard rate. Despite higher bills for PG&E and SCE customers, analysis of the first wave of survey data revealed that customers on a TOU rate did not tend to experience increased economic hardship compared to members of corresponding control groups on a standard rate. Table 5 exhibits all statistically significant ($p<.05$; t-test) segment differences in economic hardship by rate and IOU; economic hardship was assessed for all customers (including non-low-income). As seen in the table, none of PG&E's pilot TOU rates resulted in increased economic hardship (including among hot climate, low-income customers). Conversely, of the 30 segments treated in SCE's territory, only three of SCE's segments experienced increased economic hardship following the first summer of the pilot, all of which were low-income segments in hot climate zones. Interestingly, both of SDG&E's TOU rates demonstrated decreased economic hardship for some non-low-income groups, corresponding to the finding that TOU rates actually resulted in slightly lower bills for many of SDG&E's customers. As seen in the table, senior segments (irrespective of income) did not significantly vary in economic hardship regardless of assigned rate plan (in fact, seniors demonstrated some of the best load shifting behaviors; see Folks 2017 for a deeper dive on this phenomenon).

[8] Full descriptions of the rates, load and bill impacts, and survey methodologies can be found in George et al. 2017a, 2017b, and 2018.
[9] Ibid.

Table 5. Observed differences in economic hardship following first summer in pilot*

IOU	TOU Rate 1	TOU Rate 2	TOU Rate 3
PG&E	No effect	No effect	No effect
SCE	No effect	↑ Hot Climate 100-200% of Federal Poverty Guidelines	↑ Hot Climate CARE/FERA ↑ Hot Climate CARE/FERA - on or eligible
SDG&E**	↓ Moderate Climate Non-CARE/FERA ↓ Cool Climate Non-CARE/FERA	↓ Moderate Climate Non-CARE/FERA	-

*↑ denotes significantly ($p<.05$; t-test) higher economic index scores and ↓ denotes significantly ($p<.05$; t-test) lower economic index scores for the listed TOU segment compared to the analogous control group.
** SDG&E did not pilot a third TOU rate and did not sample hot climate customers due to their extremely low incidence rate in the SDG&E service territory.

As seen in the table above, TOU rates did not consistently result in increased economic hardship for low-income customers after their first summer on the rate. The only limited evidence of increased hardship was found in hot climate zones, where TOU rates could be particularly problematic for low-income household budgets in areas that heavily rely on air conditioning during the summer. As previously noted, comparatively lower bills in winter months (than what would be experienced under standard tiered rates) are theoretically supposed to make up for potentially higher bills in summer months, with billing data confirmed this tradeoff trend. As it relates to economic hardship, none of SCE's low-income segments demonstrated any statistically significant differences in economic hardship between treatment and control customers in the second survey (following the winter and spring months). Nonetheless, based on the results of this study, the IOUs will exempt low-income customers (specifically, those on CARE/FERA discount programs) living in hot climate zones from future TOU default enrollments (however, these customers are free to opt-in).

Conclusions and Recommendations

The results of the final case study suggest that TOU rates do not cause widespread economic hardship for California's most vulnerable households, even if their bills may seasonally increase after transitioning to a TOU rate plan. However, the study demonstrates a clear interaction between climate and income: the rare instances of increased hardship via TOU rates were only among select customer segments that were both low-income and located in hot climate zones, and this effect was only found in the summer and was ultimately nullified after the subsequent winter and spring months. This finding highlights how the results from this study are within the context of California's specific climate and technological environment*:* elevated electricity use stemming from weather conditions in California is predominantly the use of air conditioning as a response to moderate to extreme heat. Nonetheless, the study's lessons are not limited in their application to solely summer-peaking utilities with moderately high electricity prices. For example, similar economic hardship outcomes may occur in extremely cold climate zones where electric heat is common in residential applications. The interaction of rate structure,

climate, income, and HVAC fuel type reveals an important policy implication for those planning to transition residential customers to TOU rates: utilities should consider implementing preventative measures that ensure low-income customers with electric HVAC systems in extreme climates are not economically burdened by the transition. Accordingly, the California IOUs took a myriad of preventative measures to ensure low-income customers would not be overburdened by TOU rates, including exempting low-income customers in hot climate zones from statewide default activities, providing baseline allowances for all-electric households, offering bill protection price guarantees, allowing customers to switch back to their previous rate at any time, and extensive educational campaigns that teach customers about behavioral tactics that can help keep their bills down on TOU rates.

The case studies highlighted in this paper are by no means a comprehensive assessment of the low income experience on TOU and other dynamic rates, and continued research on this area is needed before drawing any definitive conclusions. However, the empirical findings presented in this paper present a compelling challenge to common preconceptions regarding how low-income customers may fare on TOU rates.[10] Although they may be less aware of alternative rates, and the uninitiated may be less eager to try them than their non-low-income counterparts, the results presented in this paper represent a convincing argument that TOU rates may do more good than harm to low-income customers. Not only do they have load shapes that are more likely to result in bill savings on TOU rates (compared to standard volumetric rates), but our evaluation research reveals that low-income customers are just as capable as anyone else to make load shifting behavior changes. If anything, volumetric rates constitute an economic injustice to low-income customers, whereas levelized pricing inequitably penalizes those who can least afford to subsidize the peak-prone energy use of non-low-income households. Research conducted by the Citizens Utility Board [of Illinois] corroborates this assertation, as they found that volumetric rate designs can result in overpayment from low-income customers due to their flatter load shapes (Zethmayr 2019).

Clearly, TOU rates can benefit low-income customers. However, the research presented in this paper suggests they may be some of the least likely to voluntarily participate. So how do utilities encourage their low-income consumers to participate in alternative rates like TOU? Defaulting customers onto alternative rates is the obvious answer, but default approaches may not be politically viable in certain regulatory frameworks. Findings from studies referenced in this paper reveals some key factors that demonstrably increased awareness and engagement from low-income customers, ultimately elucidating potential avenues for increasing low-income customer enrollment in alternative rates.

Strategy #1: Increase Customer Awareness of Alternative Rates

In our 2019 rates study for SECC, we found that low-income customers had particularly low "rate literacy:" although they were similar to non-low-income customers in that nearly half indicated they were unsure what type of rate plan they currently have, low-income customers

[10] Herman K. Trabish's 2019 Utility Dive article provides excellent coverage of the debate over whether TOU rates uniquely disadvantage low-income customers, including anti-TOU arguments commonly posited by rate payer advocacy groups. https://www.utilitydive.com/news/an-emerging-push-for-time-of-use-rates-sparks-new-debates-about-customer-an/545009/

were significantly less aware of alternative rate concepts than non-low-income customers. Further, conjoint analysis revealed that low-income customers were some of the least interested in alternative rates of all demographics tested. However, respondents (regardless of income status) who were aware of alternative rate plans demonstrated some of the highest preference for them and were significantly more interested in enrolling in a TOU rate plan than consumers who were unaware of alternative rates prior to taking the survey. Similarly, the 2018-2019 PG&E default TOU pilot study found that preference for and satisfaction with TOU rates significantly increased once low-income customers were defaulted onto the pilot (and therefore had the opportunity to increase their familiarity with them). Collectively, these findings suggest that increasing awareness of alternative rates is a key pathway to encouraging enrollment among low-income households. Marketing, education, and outreach campaigns should be employed in any alternative rate campaign – be it an opt-in or default format. Utilities should seize this opportunity to educate their customer base about the alternative rates they offer, and to the extent possible, should use marketing tactics that have empirically greater success with low-income customers in their jurisdiction.

Strategy #2: Offer a "Cash" Sign-On Bonus

As demonstrated in our 2019 rates study for SECC, a one-time $50 bill credit offer made great strides in piquing low-income customers' interest in alternative rates. That study suggests that utilities can maximize low-income household enrollment via cash incentive offers. Considering that the bulk of rate payer-sourced utility cash incentives (e.g., rebates) have historically eluded the low-income sector, financial incentives for low-income enrollment in alternative rates may contribute to utility energy justice goals.

Strategy #3: Advertise a Price Guarantee (Bill Protection) for the First Year or Two

Many utilities offer bill protection for residential customers' first year on alternative rates, where the customer can try the rate "risk free" in that they will receive bill credits as payback if they end up paying more on an alternative rate than what they would have on their prior rate. Utilities commonly offer these to both standard income and low-income residential customers, although bill protection may be more generous for low-income enrollees (e.g., the New York demand rate mentioned in the Awareness section offers an extra year of bill protection for low-income customers and provides the bill credit every quarter, whereas non-low-income customers receive any owed bill credits at the end of their first year on the rate). Although low-income customers preferred bill credits to bill protection in our 2019 rates study for SECC (which made these options mutually exclusive), our evaluation of PG&E's TOU default pilot found that low-income customers rated bill protection as highly important on their decision to stay on the rate (i.e., not opt-out), with low-income customers rating bill protection as significantly ($p<.05$; t-test) more important to their decision than non-low-income customers. Although the research presented in this paper reveals that many low-income customers will naturally experience bill savings on TOU rates (and many will experience even greater savings via load shifting behaviors), offering and advertising bill protection simultaneously serves as an important safeguard and a successful recruitment marketing tactic for low-income customers.

Final Thoughts

Thanks to strides in advanced metering infrastructure (AMI), time varying rates are poised to revolutionize modern electricity markets. Given the rapid spread of renewable energy sources and DERs, alternative rates will be increasingly important for optimizing net demand and ensuring that customer rates are more commensurate with utility costs. Thus, alternative rate structures such as TOU are likely to become the norm, rather than the exception. For those wondering how to make utility services and offerings more equitable, TOU rates may be one such answer.

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