Title

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Journal

Energy Efficiency, 12(1)

ISSN

1570-646X

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Publication Date

2019

DOI

10.1007/s12053-018-9703-z

Peer reviewed

Energy Efficiency
https://doi.org/10.1007/s12053-018-9703-z

ORIGINAL ARTICLE

"Everyone has a peer in the low user tier": the diversity of low residential energy users

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Received: 1 November 2017 / Accepted: 11 June 2018

Abstract Low residential energy use is typically associated with undesirable characteristics, such as poverty, thermal discomfort, or small dwelling size. The association of low energy use with deprivation has been an obstacle to promoting more aggressive goals for reduction of residential use. However, there is little research on the composition of the low user population. We investigated the demographics, behavior, and satisfaction of the lowest 10% of electricity consumers in Sacramento, CA, to see what attributes best correlated with low use. California, like many other regions, has GHG emissions goals requiring drastic reductions in residential consumption. Households in Sacramento's lowest decile of electricity consumption already live at electricity consumption levels consistent with the goals for 2050. Our investigation of 700 of these households found that diversity of low users with regard to age, income, education, appliance ownership, and dwelling characteristics is similar to that of the general population. Low-use households tend to be smaller, but not enough to explain the entirety of low usage. Surveys and interviews revealed that those in the lowest 10% typically pursued low consumption deliberately and enthusiastically and were aware of their status as low users. Conversations about energy conserving strategies were embedded in their social lives. They employed diverse and creative strategies to maintain thermal comfort without excess energy use, often exceeding expert recommendations. Finally, the distribution of self-reported quality of life was no different from that of the general population living at much higher consumption levels. Overall, the key determinants of low use were a positive engagement with improvisation and experimentation, and the salience of energy in personal or social life. The population of low users should be treated as a valuable source of peer advice and lifestyle modeling.

Keywords Household energy consumption · Residential energy demand · Energy behavior · Energy poverty · Peer communication

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Introduction

Parties to the 2015 Paris Climate Agreement have agreed to mitigate climate change by reducing emissions of greenhouse gasses (GHG). Each country must set goals, establish plans, and regularly report on their actions. Meeting these goals will require large changes in the way we produce and consume energy. In California, USA, two pieces of legislation anticipated the Paris Climate Agreement by a decade. The Global Warming Solutions Act of 2006 sets 2020 as the deadline for GHG

Published online: 24 July 2018

reduction to 1990 levels (California 2006). Further down the road, Governor Schwarzenegger's executive order of 2005 requires the reduction of GHG emissions to 80% below 1990 levels by 2050 (Schwarzenegger 2005). The steps toward achieving these ambitious goals are outlined in the state's Scoping Plans, which rely heavily on technological advances, shifts in energy supply, upgrades to energy infrastructure, and improvements in the efficiency of end use devices and buildings (California Air Resources Board 2008; Energy and Environmental Economics 2009; Long 2011; California 2016). This preference towards technological solutions is typical of most large-scale scenarios for meeting long-term climate change objectives (e.g., Pacala and Socolow 2004).

Reduction of residential energy consumption is an important component of climate change mitigation. At present, California's residential sector accounts for about 13% of the state's total GHG emissions (California Air Resources Board 2017). Most forecasts of residential sector demand extrapolate from the current usage of "average" households, and factor in anticipated population change, impacts of building codes and appliance efficiency regulations, and innovations in renewable energy sources. We believe this type of scenario building—projecting "average" demand and relying heavily on future technological developments for reduction—has several weak spots. First, it relies on heroic assumptions about the success of current measures, or the timely emergence of innovations. These are not guaranteed, and failure of any of them means goals will not be met. Second, with rare exceptions (e.g., Dietz et al. 2009), such scenarios disregard the role of norms and preferences in energy consumption. Energy demand is seen as elastic to the extent that technological improvement brings changes, but personal or household choice is not considered a significant factor in reduction. Finally, the unexamined use of "average" household consumption figures obscures a great deal of potentially useful information about how demand works, and how it might be changed. The implication that "average" consumption is also "normal" consumption, and therefore difficult to change, is a barrier to energy savings.

We believe that in order to assess the hidden potential for GHG reductions in the residential sector, it is essential to research heterogeneity in energy use. By "heterogeneity," we mean variation *within* demographically similar groups, not *between* dissimilar groups differentiated by age, income, race, education, home size, and so forth. Although these demographic factors are the usual explanations for variation in energy consumption, we had anecdotal experience of households that did not confirm to stereotypes, such as high income households that used little energy, or vice versa. We thought that a systematic study of heterogeneity could bring to light other circumstances, practices, and attitudes that contributed to high or low residential consumption. We also hoped that "normalizing" heterogeneity would dispel the idea that today's "average" use represents a normal or necessary level.

Jane Jacobs was early advocate of the study of "unaverages" in her pioneering work on urban sociology. She argued that statistical methods focusing attention on averages were inadequate for understanding a dynamic system such as a city. Instead, the most useful and interesting information could be found at the margins, amongst the exceptions and outliers: "City processes in real life are too complex to be routine, too particularized for application as abstractions. They are always made up of interactions among unique combinations of particulars, and there is no substitute for knowing the particulars" (1961). Energy consumption is a similarly complex socio-technical system, an interaction between devices and structures, and human choices, attitudes and behaviors. We need "unaverage" research to explore how that system works, and find out what kind of useful knowledge exists at the limits. Taking inspiration from Jane Jacobs, we decided to look at the long end of the energy consumption tail, by examining the particulars of very low usage.

We had additional reasons for choosing to study the lowest users, beyond the general value of "unaverage" examples. Current expert proposals to reduce residential sector emissions are not adequate to achieve to California's goals. However, the lowest decile (10%) of electricity consumers in Sacramento were *already* living at the consumption levels prescribed for 2050. We hoped to take advantage of this natural field experiment, by learning more about these people. If we could understand their energy habits, we could improve outreach efforts by removing the stigma that very low energy use meant deprivation and discomfort.

The literature: heterogeneity, energy poverty, social communication

Research on heterogeneity in energy consumption is scarce, and research specifically on low use is even scarcer. Variation in household energy consumption across households was studied extensively in the 1970s and

1980s (Socolow 1978; Diamond 1984; Schipper et al. 1989; Hackett and Lutzenhiser 1991). Studies of variation in energy use direct attention to the role of social and demographic factors, but also point to the circumstances under which the social nature of energy consumption is revealed (Hackett and Lutzenhiser 1991). Variation among residential energy customers has also received attention in recent years via information-driven social norm messaging programs that target higher users through information mailed to customers, including a usage comparison across demographically similar households and a series of recommended actions (Dougherty et al. 2011). Another outreach effort, pioneered by the Gainesville Regional Utility, puts customer usage information on the web for anyone to access. The hope was that by encouraging customers to compare their usage with other households, the large differences in consumption would provoke reductions in use.[1] Others, such as Seattle City Light, have studied variation among their residential customers, as well as high usage, as a way to identify opportunities for large savings (Seattle City Light 2010, also Meier 2010).

Although low usage is obviously one component of the variation in energy consumption discussed above the energy research community has paid very little attention to low usage specifically. Two exceptions were Hackett's work on the energy habits of rural "homesteaders" in Northern California (1980), and Johnson et al., who studied energy consumption among the Amish (1977). These were groups whose identity revolved was based a rejection of mainstream values, consumption patterns, and lifestyle. The groups were outliers to mainstream society, but themselves culturally and demographical homogeneous. We took these studies as a point of departure, but instead inquired into low users who are fully embedded in a mainstream urban population. Their status as low users is invisible to members of the society within which they live, and it was precisely this invisibility—or seeming normality—within a general population that made these low users potentially valuable as peer models of low consumption.

In contrast to the scarce analysis on heterogeneity in energy use, there is an extensive literature on fuel poverty, energy poverty, and energy insecurity (Boardman 1991 and 2012, Thomson and Snell 2013, Hernandez 2013, Sovacool 2015, inter alia). This is a mixed blessing. On the one hand, highlighting the struggles of those unable to afford basic energy services is a necessary, even urgent task. On the downside, the very success in heightening awareness of fuel poverty may contribute to the assumption that low energy use necessarily indicates deprivation. If one assumes that households consuming little energy do so because they have no choice, it follows that they have no agency in the matter. They are not likely to be a source of lessons or solutions scalable to the "typical" population; rather they must be the object of aid and education. As the diversity among low users continues to be neglected as a research topic, the cycle of ignorance is perpetuated. (Indeed, our proposal to study the lowest 10% of energy consumers was met with puzzlement, and reiterations of the conventional wisdom that there was nothing helpful to learn.) The lack of analysis of low users is not simply a research gap; it has real world consequences that affect many aspects of energy policy. Our assumptions about low-users shape subsidies, taxes, energy rate structures, and programs directed towards this group.

In our investigation of the relationship between social communication and low energy use, we were influenced by the literature on promoting norm change through personal persuasion and social marketing (Cialdini 1984 and 2016, McKenzie-Mohr 2011). Our findings generally supported the idea that conversations with familiar figures (friends, neighbors, extended family) were a powerful tool for change, whether in sustainable lifestyles or other areas of behavior.

Research objectives

At the outset, we had several broad objectives. First, we wanted simply to understand who low users were, in terms of basic demographic attributes and life circumstances. We used survey data to compare the lowest decile (10%) of electricity users to the general population of the same service area. We looked at a range of demographic attributes, such as age, income, ethnicity, education, dwelling size, and number of household occupants. We wanted to test the prevailing assumptions about low energy consumption by looking not just at average values, but by considering diversity and distribution within the tier of low users.

Our second objective was to gain a more nuanced insight, beyond the basic demographics, of the pathways to low usage. We hoped that the responses to survey

[1] See http://gainesvillegreen.com/. The opposite effect, i.e. provoking an increase in consumption by lower-use households, is of course also possible.

questions and telephone interviews would reveal the mechanics whereby people in the lowest decile achieved their low usage. What behaviors, strategies, and attitudes could we find among our low user group that might differentiate them from demographically similar people with higher energy consumption? Did they actively pursue the goal of low usage, or was it something that just happened as the ancillary result of circumstantial constraints? Did they scrupulously follow expert advice, or did they innovate on their own? Did they interact with other low users, or were they alone in their pursuits? Were they more tolerant of discomfort? How satisfied were they with their quality of life, and how did that relate to energy use?

Next, we wanted to create an array of plausible household profiles within the low use tier. In the long run, we hoped that utility companies could improve energy efficiency outreach by using peer groups that matched low-use households with normal-to-high use households. We created profiles by combining economic, social, and philosophical criteria, and estimated their relative weight within the overall lowest decile.

Finally, we wanted to find ways to distinguish between low use per se, and energy poverty/fuel poverty/ energy insecurity. At present, there is no established methodology for doing so. Indeed, the definitions of these terms vary widely amongst experts and nations, and even the issue of whether greater uniformity would be beneficial is the subject of much debate (European Parliament 2016, pp. 19–20). But at the most basic level, it is safe to assume that energy poverty is an involuntary and unhappy condition, the result of constraints not chosen by the consumer. Starting from this basic premise, we experimented with other ways of assessing the presence of energy poverty, by investigating the subjective energy experiences of our respondents along axes such as voluntary versus involuntary low use, or high versus low quality of life.

Methodology

Our study of households consuming little energy was conducted with the cooperation of the Sacramento Municipal Utility District (SMUD), based in California's state capital.[2] SMUD is one of the largest municipally owned utilities in the USA, providing electricity to 900 miles^2 (2330 km^2) of urban and suburban zones, containing 1.4 million residents.[3] Our sample pool were the households in SMUD's lowest decile of electricity consumption, based on average monthly usage from 2008 to 2010. We excluded households known to be using solar, households whose erratic usage pattern might indicate a second home, and households who had not lived at their current residence for the entire span of the study period. On the other hand, we rejected SMUD's suggestion to exclude households below the threshold of 200 kWh/month on the assumption that they represented either vacancy or measurement errors. Doing so would have eliminated precisely the kinds of outliers we hoped to study; indeed some of SMUD's occupied households used as little as 52 kWh/month.[4]

The utility's database allowed us to calculate summary descriptive statistics describing technical and socio-economic variables within different subsets of households. We used regression analysis to examine the relationships between these variables and energy consumption in the general population. To supplement the utility's data, in 2012, we conducted an in-depth survey of a random sample of homeowners and renters from the lowest decile of consumption. The survey gathered information on household composition, ethnicity, habits, appliances, alternative fuel use (i.e., natural gas), self-perceptions of energy profiles, sources of energy information, and social interactions around energy. Response rates for the survey were 16% for renters (607/3876) and 18% for homeowners (113/630). The final phase of the analysis was telephone interviews with homeowners who had completed the survey and indicated willingness to participate in an interview. These open-ended discussions delved more deeply into attitudes and behaviors. Of 39 eligible homeowners, we conducted interviews with 21 households. The survey questions were designed to cover the full range of energy end-uses, but it soon emerged that summertime thermal comfort was central to respondents' thoughts on energy services. The telephone interviews focused chiefly on cooling strategies.[5]

[2] The full report is Reuben Deumling et al. (2013): "Identifying Determinants of Very Low Energy Consumption Rates Observed in Some California Households". Available at https://www.arb.ca.gov/research/apr/past/09-326.pdf .

[3] See https://www.smud.org/en/about-smud/company-information/company-profile.htm

[4] Deumling et al. (2013), p. 7, Figures 5.1 and 5.2. Monthly usage for the overall population ranged from 50 to 1850 kWh/month. The boundary of the lowest decile lay at about 330 kWh/month.

[5] For regression table see Deumling et al. (2013), pp. 77–73; for survey questions pp. 76–83; for interview template pp. 84–85.

How do low users compare to the general population?

Our first task was to compare a random sample of low electricity users with the overall customer population served by SMUD. We began with the basic demographic attributes obtainable from the utility's database and the US Census: age, education, income, household size (number of persons), and dwelling type. Regression results[6] supported many of the common assumptions about low energy consumers. Holding all other variables constant, households with more people, higher income, larger floor area, and higher educational level (of head of household consumed more electricity per month on average. Higher energy consumption was also associated with older residences, younger household heads, and longer periods of continuous residence. However, a regression analysis of linear relationships amongst variables only shows the average effects of variable change. It was indeed true that on average, Sacramento's low user households were poorer, smaller, more elderly, less well educated, and had fewer people than the general population. But over-reliance on averages was precisely our objection to existing approaches, in that it obscured useful inferences from the diversity within the low users tier. We wanted to know whether the typical theories about low use (such as poverty) could *adequately* explain the entire phenomenon, or whether low users were diverse enough to require further, alternative explanations. Thus, it was more useful to compare the diversity of low users with the diversity of the general population. Our investigation revealed that for most demographic attributes, variation within the lowest decile was similar enough to variation within the general population to merit further investigation of alternative explanations. The presence of all demographic profiles within the lowest decile meant there was no a priori reason why low usage could not be replicated amongst similar consumers with higher use.

Of the three most common theories about the causes of unusually low energy use—low income, small dwelling size, and few household occupants—our analysis led us to reject the first two as inadequate, in and of themselves, but accept the third.

Income analysis of owner-occupied households showed that in the three middle bins (representing annual incomes from $30 K to $150 K USD), the distribution of lowest decile group and the general population differed by no more than 5%. The most noticeable difference between low users and the general population was that the percentage occupying the lowest and highest income bins (representing annual incomes < $30 K and > $150 K) was essentially reversed. In the case of renters, the distribution of the lowest decile again matched the general population fairly well in the broad middle range of incomes, with conspicuous divergence in the highest income bin (where low usage renters were almost invisible) and the lowest (which contained 46% of the lowest decile versus 32% of the general population). In summary, there is no denying that poor renters are overrepresented in the lowest decile. But the majority of low usage households dwelt in the middle-income ranges. Since middle class (and even high-income) households were well-represented, we rejected low income as an adequate explanation of low electricity use (Fig. 1).

With regard to dwelling size, the floor area of the average owner-occupied home in our lowest decile was indistinguishable from the general population; while the size of lowest decile rental units was somewhat smaller than for the general population.[7] Analysis was hampered by the fact that rental unit data is logged in 500 square foot bins, so the comparisons were somewhat imprecise. But since 46% of the lowest decile population were owners, the range of home size for the entire lowest decile (homeowner + renter) was still quite broad. We therefore rejected the small home theory as inadequate, despite the somewhat ambiguous conclusion for renters alone.

Finally, with regard to number of household occupants, the average headcount for our respondents' households was 1.6, which was significantly lower than 2.6 for the general population.[8] The high incidence of single-person households, and the scarcity of large households, was true for both owners and renters. We accepted that low occupancy was a cause of low usage, in and of itself.

[6] For the sole purpose of the regression analysis, we compared the lowest quartile (rather than decile) of electricity customers with the general population of the SMUD service area. In contrast to the rest of the study, the goal here was to establish linear relationships between electricity usage and the variables of interest; thus, the use of the somewhat broader data set was preferable. Results from regression models are presented in Deumling et al. (2013), pp. 72–73, Table A.1.

[7] Deumling et al. (2013), p.19, Figure 6.9.

[8] Deumling et al. (2013), p. 17, Figure 6.6. We further compared the lowest decile with the general population as to age distribution (Figures 6.3, 6.7, and 6.8) educational attainment of household head (Figure 6.2), and ethnicity (Figure 6.4).

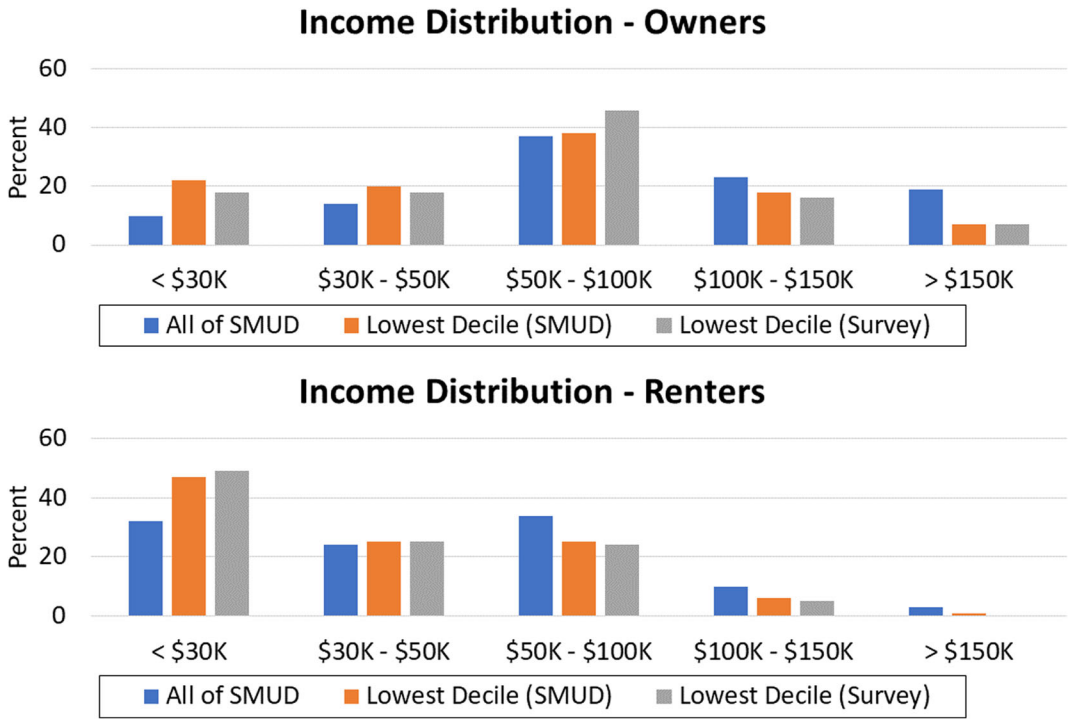

Fig. 1 Income distribution of households in Sacramento, CA, USA (Deumling et al. 2013, p. 13, Figure 6.1 comparing incomes of SMUD's overall customer population, lowest decile of electricity consumption, and our survey respondents. See also p. 16, Figure 6.5.)

Psychology and behaviors of low users

While the average lowest decile household in Sacramento had somewhat lower income, home size, and occupancy than the average general population household, the diversity of low user households was great enough to merit investigation into other explanations of low use. We used the survey and the telephone interviews to explore subtler, less obvious attributes that might distinguish lowest energy users from their demographically similar fellow citizens. Again, the direction of our inquiry was informed by prevailing myths about low usage. For example, given the usual assumption that low use is the undesirable result of constraints, we looked in the opposite direction: low use as an intentional goal. Did some households actively pursue reduced energy consumption? Did they know they were doing something different, and if so, what? Were they more avid about seeking advice from energy professionals, such as their utility provider? Or were they more likely to rely on peer information and DIY approaches? This stage of the study was necessarily exploratory: our goal was to find suggestive correlates that could guide future control-group studies searching for firm causes.

The survey included 19 questions (14 multiple-choice, five open-ended) on energy related behaviors and beliefs. It quickly became clear that summertime cooling strategies were the central point of reference for users' mental models of energy use: even when questions did not specifically ask about it, responses centered on air conditioning (A/C). Participants in the subsequent telephone interviews also had a great deal to say about their personal philosophies of thermal comfort. This was not surprising, given Sacramento's infamously long, hot and humid summer season. (The survey was conducted during the summer, which no doubt further elevated the salience of this subject.)

A more surprising result was that income, A/C use, and electricity consumption did not align in the way one might expect, that is, higher income corresponding to higher A/C use and thus higher electricity consumption. The survey asked subjects if they owned an air conditioner (either window or central), and then asked A/C owners to estimate their frequency of usage in two differently worded questions. As one might expect,

frequent A/C use did correlate to higher overall electricity consumption.[9] Those who reported using A/C "regularly" or "very often" typically consumed around 300 kWh/month, while non-owners, non-users, and those who used it "once or twice a year" consumed only 200 kWh/month. However, the mere *ownership* of A/C was in itself a poor predictor of usage. Those who owned A/C but who reported using it "never," "once or twice a year," or "rarely" ranged from 15 to 35%, depending on question wording and number of choices. More interesting still was the income distribution for non-owners, non-users, and rare users, a total of 39% of respondents. As shown in Fig. 2, they are not grouped off to the left in the low-income bins, as the common assumption about low users would predict. Instead they are distributed fairly symmetrically, with homeowners showing a peak between $50 and $100,000, and renters distributed even more evenly across the brackets.

These data suggested that avoiding A/C use was a behavior that a significant number of households had chosen, rather than one that they had been forced to adopt. Many of our respondents could have afforded A/C but preferred to achieve thermal comfort in the summer heat by other means. This was an early clue that the conscious, deliberate pursuit of low consumption was at least as significant as circumstantial constraints. This was further born out by answers to the open-ended survey questions, and especially by the many comments in the telephone interviews, describing A/C non-ownership or non-use as a matter of pride, or an opportunity to be creative, rather than as a limitation.

Self-awareness

Our survey included a number of questions designed to detect whether or not low electricity use was the result of a deliberate, positive effort.[10] Questions 14 and 19 asked respondents to rank themselves relative to others in their circle. Did they believe their electricity usage to be lower or higher than friends and neighbors? Did they keep their homes warmer or cooler during the hot season? Questions 15, 16, and 17 then asked them to explain their self-ranking. Did they describe deliberate actions taken to lower their use? Did they cite factors that could be interpreted as constraints? Or did they simply claim ignorance? Finally, Question 34 posed an open hypothetical: "IF you were to learn that your electricity usage was lower than average", how would you explain it?

Responses to Question 14 showed that close to 70% of homeowners and just over 50% of renters believed their energy use to be lower than that of their neighbors.[11] The proportions were similar for Question 19: 67% of homeowners and 56% of renters thought that their homes were warmer in summer (i.e., less cooled) than others.[12] The explanatory responses to Questions 15, 16, 17, and 34 fell into four broad categories: circumstantial constraints, motivations and beliefs, actions and behaviors, and an opaque resistance to explanation we dubbed "just how it is."

We coined the rubric "just how it is" to encompass two overlapping but not identical types of respondents: the unaware and the uninformative. Questions 14 and 19 had ascertained that some respondents were simply unaware that their usage was atypically low (even though it in fact was). On the other hand, Questions 15, 16, 17, and 34 showed that some respondents realized their usage was probably low, but had no explanation for that fact. These people somewhat resembled the "constrained" consumers, in the sense that low usage was the unconscious product of their habits, but unlike constrained consumers they did not feel there was anything noteworthy or even explicable about their energy use. (It is possible that their behaviors were of such long standing that they were no longer able to articulate them—i.e., they had become fully embedded practices—but the true nature of this type of low user remains opaque.)

About 23% of both homeowners and renters cited constraints in their explanations, such as living alone, not at home much ("I work all the time"), small dwelling size, and limited finances ("I can't afford to use more energy").[13] Notably, financial constraint was the least common of these.

With regard to motivations and beliefs, we did not originally intend to explore this dimension, and

[9] Deumling et al. (2013), pp. 23 ff, and Survey Questions 7 and 18.

[10] Here and in all subsequent mention of survey questions, the document is reproduced in Deumling et al. (2013), pp. 76–83.

[11] Deumling et al. (2013), p. 38, Figure 6.24.

[12] Deumling et al. (2013), p. 41, Figure 6.27. Even respondents who did *not* believe their energy use to be lower (or their home less cooled) than that of their neighbors may still have recognized themselves as low users: given that our pool was a full 10% of the population, their neighbors could also have been low users.

[13] Deumling et al. (2013), p. 27, Figure 6.21.

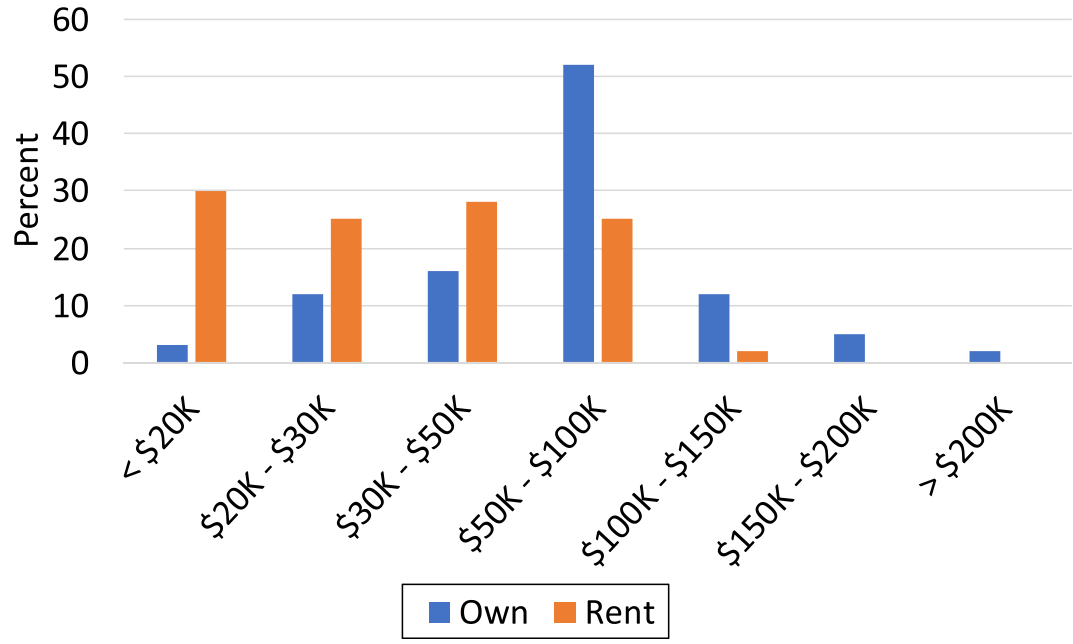

Fig. 2 Income distribution of households using little to no air conditioning (Deumling et al. 2013, p. 25, Figure 6.18.)

none of our questions specifically asked it. Strictly speaking, motivations are a rationale for low use behaviors rather than a description of the sort we were originally interested in. Nevertheless, a number of respondents spontaneously mentioned motivations and beliefs, such as concern for the environment. Typical comments were that "wasting water, gas and electricity is immoral," that they were "conscientious" about their impact on the planet, or that it was a virtue to be "frugal" or "conservative with energy". Others said they were simply happiest when living "very simply but with quality". Motivation became significant as an emergent finding on what differentiated low users.

The richest feedback was in the area of conscious actions. A majority of both renters and homeowners mentioned having deliberately "done something" to lower their energy use.[14] Their lists were extensive and heterogeneous, mentioning investment in energy efficient devices and technologies (CFLs, Energy Star appliances, double-glazed windows, HVAC upgrades); functional substitutions (cold instead of hot water for laundry, space heaters instead of central, clothes line instead of dryer); and low energy routines and habits (adjusting clothing and bedding, taking shorter showers). Of course strategies for minimizing energy use while staying cool in summer were prominent. These included setting the A/C no lower than a certain minimum, running it only when outdoors was over 100 °F (38 °C), or never when out, or never at night. Also mentioned were modifications to the home and surroundings (shade trees, weather stripping, insulation, tile floors, double pane windows, programmable thermostats; alternative cooling technologies (fans, swamp coolers); summer-specific changes of routine (lighter clothing, sleeping on ground floor, preparing cold meals); and a diurnal cycle of opening and closing doors and windows to take advantage of the Delta (evening) breeze.

We now had our first estimate of the breakdown between those whose low usage was the result of circumstantial constraints, and those who deliberately chose to pursue it as goal. A majority of consumers in the lowest decile, across a range of demographic groups, believed their low usage due at least in part to active, conscious effort. Although the estimate was crude, and the line between "constrained" and "conscious effort" was sometimes ambiguous,[15] it was clear that there were multiple pathways to low

[14] Deumling et al. (2013), p. 28, Figure 6.22.

[15] Some respondents mentioned both constraints and voluntary pursuit of low use.

usage. Since the path of active, conscious pursuit of low use was poorly covered in the literature, the salient attributes of low users merited further investigation.

Engagement

An important and unresolved issue in the attempts to reduce residential energy consumption is the relative effectiveness of advice from experts or specialists, versus peer influence. At present, utilities and government agencies put a great deal of into top-down outreach, such as home improvement checklists, published usage data, incentives, subsidies, and "nudges." In contrast, establishing frameworks for peer to peer knowledge transfer is rare. As a rough gauge of low users' degree of reliance on expert advice, the survey included two questions on whether they had availed themselves of energy audits or incentive programs offered by SMUD. Fewer than 20% of respondents reported having had a home energy audit. Somewhat more (< 40%) had participated in some kind of incentive program (window or central AC, furnace, fan, thermostat), general appliances, including water heaters and refrigerator rebates, and envelope upgrades. These numbers seemed low, but we needed more insight into the role of professional advice. As we perused the lists of energy saving actions taken by our "deliberate" low users (in the section above), it seemed that a common characteristic was that they exceeded professional advice. It is not that low users ignored expert advice—their responses clearly reflected attention to SMUD's outreach materials—but this advice was treated a point of departure rather than an endpoint. Engaged, pro-active low users came up with their own standards and solutions that exceeded official recommendations, or else augmented them with do-it-yourself approaches.

It was instructive to compare the list of cooling strategies on the SMUD website[16] at the time of our project with those adopted by our respondents. All of the utility's recommendations appear at some point in our low users' lists, but the reverse was not true: the low users had approaches that the utility did not mention. For example, the idea of simply shutting off the A/C was conspicuously absent from SMUD's recommendations. The evening routine of opening doors and windows to catch the Delta breeze—the second-most common item mentioned by renters—was also absent. SMUD's suggested minimum A/C setting was 78F, lower than that reported by our respondents. Very low-tech folk remedies—a damp towel around the neck, setting a bowl of ice cubes in front of the fan—had no place on the utility's list. Adaptations to the peculiarities of an individual's domestic routines or dwelling (orientation, age, layout, etc.) were beyond the scope of the master list. Although we focus here on cooling strategies, in fact the desire to exceed expert recommendations pertained to other end uses as well, such as some users' habit of unplugging devices when not in use.

Most importantly, the missing element in the utility's outreach was an encouragement of individual initiative—the type of iterative experimentation whereby a consumer might acquire proficiency in energy conservation. And yet the willingness to strike out on one's own was precisely the quality that came through clearly in low users' own accounts of their pathways. Their characteristic attitude toward energy conservation one of active engagement in the subject: the pleasurable pursuit of improvement through tweaking, adaptation, and customization. Their stories often featured a mode of engaged interaction with energy using devices, in which users exercised control in ways that deviated from the scripts suggested by manufacturers or experts. It was not that low users did not want to be comfortable, but they drew the line at giving over control to thermostats or other devices.

More than 30 years ago, Kempton & Krabacher (1986) observed that it was not uncommon for people to interact with their thermostats in ways not intended by the manufacturers. Sometimes customers' decision rules eluded even energy researchers. More recently, Lutzenhiser's study of responses to California's 2001 energy crisis (2002) described a divergence between official recommendations and customer behaviors similar to our observations: expert recommendations typically specified particular thermostat settings (e.g., set thermostat to 78F, or 85F when on vacation), while many customers preferred to simply turned off their A/C.

Low use and social communication

If low users are distinguished by their tendency to think outside the box—by experimenting with DIY solutions or using technology in off-script ways—how do they learn to behave in this way? If they

[16] https://www.smud.org/en/residential/save-energy/learn-energy-efficiency/conservation-tips.htm

typically exceed expert recommendations, then what other sources of information are they drawing upon? In both the survey and the interviews, respondents mentioned conversations about their practices and beliefs, sharing their efficiency strategies and insights with colleagues, friends, and family members, and learning from others in turn. Although respondents described conversations about energy as taking place (only) "sometimes," in fact they could describe their regular interactions on the subject in detail.[17] The conversations covered a range of topics. Given the local climate, many revolved around alternatives to A/C, but other frequent topics were the challenges of making energy efficiency technologies work satisfactorily, or tips about hot weather meals, or descriptions of seasonal routines, or the small victory of convincing a neighbor to discard an energy guzzling appliance. Our respondents not only thought about energy a lot, it was woven into the fabric of their social interactions. Behavioral strategies as mentioned by these respondents are by their nature social, they are learned, and they (can) become habit—part of how one lives. Eventually, they may cease to be thought of as discrete actions, and become established norms.

Our correlation between social conversations and lower energy usage aligns well with the literature describing energy behaviors as embedded in social context, shaped by a shared understanding of what is normal and comfortable (Shove 2003, Lutzenhiser & Gossard 2000, Lutzenhiser 1993, Hackett and Lutzenhiser 1991, inter alia). Shove (2003) has described the co-evolution of domestic technologies, individual behaviors, social norms, and energy consumption. The necessary, typical, or normal services that energy is expected to provide are especially inseparable from our social norms of (in Shove's words) "comfort, cleanliness and convenience". It should not be surprising that frequent social conversations about energy are conducive to a critical re-evaluation of "normal" levels of consumption.

Quality of life: energy and happiness

Our survey included two questions on consumers' perceived relation between energy use and quality of life. The first question simply asked respondents to rate their quality of life on a five-part scale. Roughly one quarter of our low users rated their quality of life as excellent, while fewer than 10% experienced a "below average" or "poor" quality of life. These numbers reinforced our sense that the relation between energy use and quality of life was not simple. In the second question, we posed a hypothetical scenario in which consumers used more energy: they were first asked to re-scale their anticipated quality of life in this scenario, and then asked to explain their reasoning. About 65% chose "about the same," fewer than 10% anticipated that more energy would improve their quality of life, and greater than 15% expressed the opposite opinion, that more energy would lower their quality of life. (The remainder did not know) (Fig. 3).

However, it was difficult to interpret the responses to the hypothetical scenario of higher energy consumption. About 26% (of those responding to this question) said that since increased energy use would mean higher bills, their quality of life would diminish. That share corresponded well to our estimate of those who used little energy due to financial constraints. Just over 5% felt increased energy usage would lower their quality of life for social or environmental reasons, citing "social equity," "waste," "over-consumption," "saving the planet," "simple living," and "guilt." About 10% stated that more energy would mean increased comfort and therefore a better quality of life. The remainder did not offer reasons, beyond a simple reiteration of the opinion that more energy would improve or diminish their quality of life. These findings were problematic in (at least) two ways. First, respondents who believed in an inverse relation between higher energy use and quality of life were heavily over-represented. Overall, of those who re-scaled their quality of life for the hypothetical high-energy scenario only 44% then went on to offer an explanation. But for who thought that higher energy use would make them less happy, almost *all* of them elaborated on their reasons. Why were the inverse-relation group so much more motivated to respond? We also worried that since respondents interpreted "quality of life" so differently—some defining it financially, some philosophically—their responses might be incommensurable.

Profiles in low usage

The two chief takeaways of our investigation were now clear. First, the lowest decile of electricity

[17] Deumling et al. (2013), pp. 39–40 and pp. 80–81 (Survey Questions 25–27).

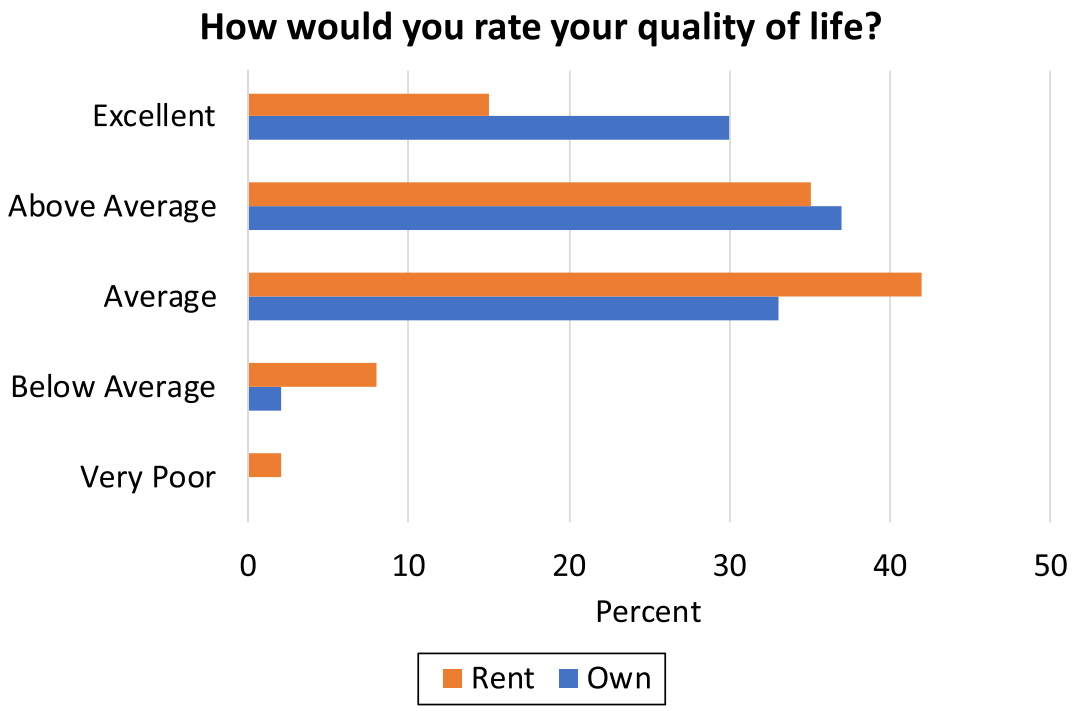

Fig. 3 Self-reported quality of life in the lowest decile of electricity consumers (Deumling et al. 2013, p. 42, Figure 6.28.)

consumers was a heterogeneous group, cutting across demographic, social, and economic categories; and second, there were multiple pathways to low energy use. Low income, and/or small household, and/or small dwelling could all lead to low usage, but there were other ways to get there as well.

Within the tier of low users, quantifiable demographic attributes (age, education and income) mixed with more intangible qualities (technical aptitude, quality of life perception, philosophy of comfort) in unanticipated ways. It was possible to be high income but low energy, or low energy but high life-satisfaction, or perfectly average demographically yet consuming far less energy than average, or apathetic about environmental motivations but nonetheless practicing a low energy lifestyle. Some combinations were more likely than others, but the makeup of our lowest decile was much more diverse than anticipated.

In the commercial world, retailers respond to market heterogeneity by creating profiles of different demographic and lifestyle groups. Targeted advertising features actors or messages chosen to appeal to highly specific segments. In theory, a similar segmented strategy could be employed in energy efficiency campaigns, by combining the profusion of consumer data with the analytics prowess of firms such as Opower. And yet this has not generally been the case: regulatory agencies and utility providers seem averse to segmented messaging. Typical efficiency checklists are one-size-fits-all and appeals to reduce consumption are aimed at the entire customer base.[18]

The next stage of our project was to explore what market segments or niches might look like in the field of residential energy demand. The eventual policy application would be to concretize efficiency messages by

[18] There have been some efforts to leverage social media to target energy reduction messages more effectively. Dougherty et al. (2011) describe data-driven social norm messaging programs that target high users through information mailed to customers, including a usage comparison across demographically similar households and a series of recommended actions. Seattle City Light has studied variation among their residential customers, as well as high usage, as a way to identify opportunities for large savings (2010, also Meier 2010). An outreach campaign by the Gainesville [Florida] Regional Utility puts customer usage information on a searchable public website "to enable us all to make better decisions about our energy usage" (Gainesville Green n.d.). Although these give the appearance of targeted outreach tailored to market niches, in fact the same behavioral strategy is deployed for the entire audience. At the other end of the usage spectrum, subsidy or assistance programs are aimed at a narrow market niche (low income consumers), but these are a form of support rather than an effort to change behaviors.

embedding them in fully fleshed portraits of real, "relatable" low-use households. Our challenge was to create profiles that realistically represented the diversity and complexity of consumers' lives; the test of their validity would be finding what proportion of our subject population fit each profile. The process of profile creations was necessarily exploratory and intuitive, but we felt it was important to combine non-commensurable criteria, because in real life economic, attitudinal, and behavioral attributes do not always align in predictable ways Of the six profiles we developed, some were defined in purely demographic terms, others incorporated behaviors, and still others featured attitudes reported in the subjective sections of the questionnaire. In some cases, we scrutinized the profile population for additional shared attributes that might sharpen our understanding of the profile. Here, we highlight some of the most interesting insights. (Because the profiles were not mutually exclusive, the percentages of qualifying populations total to more than 100).

The first profile, Well Off and Energy Efficient (18% of survey respondents) included all those in the upper levels of income, education, and home size who also indicated a pursuit of energy efficiency technologies. The chief insight here was that the energy efficiency route, combined with a fair amount of attention to energy-related habits and behaviors, allows large households with a full suite of electrical appliances to live well within the tenth percentile.

Excellent quality of life (24% of survey respondents) was based on a single criterion, self-identification of an above-average or excellent quality of life. The idea was to identify any of our low users who were very pleased with their circumstances. The category included household incomes below $20 K and above $100 K. The earlier statistical analysis had shown that low users were widely distributed across income brackets; now we also understood that *happy* low users were similarly well-distributed. There was no simple equivalence between energy use and quality of life.

The criteria for the third profile, thermally unflappable (16% of survey respondents), were (a) owning an air conditioner, (b) using it "rarely" or "never," and (c) describing quality of life as "average" or better. Since surviving the long hot summers was such a preoccupation for most local residents, it seemed important to understand people who were happy (or at least happy enough) *not* using A/C. The distribution of income within this profile was very similar to that for the previous profile, excellent quality of life.[19] The income distribution of this profile also aligned well with that of the general population: about two-thirds had incomes between $30 K and $100 K USD. In other words, the incomes of the majority of the low users who were thermally unflappable were in the same range as the incomes of the majority of the general population. Thus, the motivation for non-use was unlikely to be cost.

Ultra-low users (30% of survey respondents) were those whose energy consumption fell within SMUD's lowest 3%—that is, between 52 and 208 kWh/month—closely approximating California's 2050 target. The most striking feature of this profile was the average household size, which at 1.25 people was noticeably smaller than for all but one of the other profiles. Single-occupant households made of 80% of the profile, and 2 person households another 17%. It was nearly impossible to achieve ultra-low use with a large household, but income was much less of a determinant. Income distribution here was much more discrete than for other profiles, occurring mostly in three non-adjacent income brackets. This aligned with the earlier finding of contrasting routes to low use: the path of low-income and high deprivation versus the path of high income, high information, and high engagement.

The Sacramento average profile (22% of survey respondents) included households with demographic values that were mid-range for the general population, along with a quality of life deemed average or above average. It turned out that these households were not only "typical" for Sacramento, but also "typical" of the low user population in the sense that their approaches to low energy use were creative and diverse. Responses mentioned the usual range of strategies: home retrofits, use of fans and CFLs, infrequent use of heat generating appliances (e.g., clothes dryers), or frequent adjustment of windows. Stories from these "average" households who embrace a low energy lifestyle could be particularly persuasive to the general public. The fact that these average low users are demographically identical to their higher-use neighbors highlights the role of behavior and motivation as a key differential.

Finally, the unhappily low energy profile (5% of survey respondents) was designed to estimate the proportion of the lowest decile occupied by those matching the description of energy poverty. The basic criteria for inclusion were household income below $50,000, home

[19] Deumling et al. (2013), p. 58, Figure 7.6.

size below 1000 ft^2, and quality of life rated "below average" or "very poor." We searched for any indications that low energy use was indeed not by choice (e.g., any mention of income constraints, thermal discomfort, etc.). Finally, we looked for statements that identified low energy consumption as a (or the) reason for poor quality of life, such as expression of deprivation or unhappiness that also mentioned energy bills or thermal discomfort, or a belief that higher energy consumption would mean higher quality of life. Of course the imprecision inherent in interpreting open-ended responses meant that our estimates were necessarily rough, and further research is warranted. But taking into account all of the filters, no more than 5% of our respondents fit the profile of unhappily low energy.[20]

Further questions and future work

There are no established templates for investigating low energy use, or, more broadly, heterogeneity among energy consumers. Thus, our investigation was exploratory and conjectural: we did not know which questions would produce useful insights, or which would prove to be dead ends. At this stage, our survey could do no more than identify some suggestive correlates that might guide future work. We recognize that many of our provisional findings will need to be validated by a broader, more rigorous study that compares the attitudes and behaviors of low users to control groups drawn from the general population.

In analyzing our survey results, we worried about the typical problems of self-serving bias in the questions asking for self-assessments and social comparisons. Likewise, we were aware that self- may have affected those who were willing to continue on to the interview. A more unanticipated problem arose from our failure to distinguish clearly between "behaviors" and "motivations," when we asked subjects to account for their low energy use. Our original intention was collect descriptions of behaviors, so we were poorly prepared to deal with the spontaneous emergence of motivation-based responses. We worried about the incommensurability of action descriptions and value statements. When we investigated the relationship between energy use and quality of life, this became a particular problem. We intended to (and did) use respondent explanations to answer our question about the degree of overlap between low energy usage and energy poverty. But since the "Unhappily Low Energy" profile drew on ambiguous data, our estimate that only 5% of the low user tier are unhappy and involuntarily constrained from using more energy should re treated as a crude approximation. We hope future research on low users will benefit from our missteps.

We also hope that future research will investigate unusually high energy users. What causes, or motivates, households to use exceptionally large amounts of energy? How much energy consumption is driven by technical factors and how much by energy-intensive behaviors that are changeable? The low-income consumers within the high-user tier deserve special attention. At the same time, households that have managed a transition from exceptionally high to exceptionally low usage (or vice-versa) could offer insights into the dynamics of behavior (and technology) change.

Finally, we wondered about the relevance of our findings for other climates, or areas with less reliance on electricity than Sacramento. The central concern of our subjects was staying cool, but were their behaviors and attitudes a reasonable proxy for people in regions with more temperate summers, or colder winters? There is no research on whether philosophies and practices of thermal management are symmetrical at either end of the comfort spectrum. For the present, we simply note that in the developed world, the provision of thermal comfort uses the lion's share of residential energy, no matter the source, and is central to most consumers' conceptualization of energy services. So it seems reasonable to suppose that our broad insights about the role of self-awareness, purposive action, and peer influence are indeed relevant to other climates or fuel mixes. Furthermore, the definition of thermal comfort is more socially constructed than, say, illumination or cooking. Thus, for the purposes of understanding the malleability of energy behaviors, the study of thermal comfort practices will continue to offer more fertile data than other end uses. Finally, on a warming planet, managing grid loads during the hot season will become a central concern for a greater proportion of the world.

Conclusions: implications for efficiency outreach

Our study of Sacramento households confirmed the prevailing assumption that households using less energy

[20] For further explanation of the unhappily low energy estimate, see Deumling et al. (2013), pp. 62–64.

were on average poorer, lower occupancy, and living in smaller homes than the average for the general population. However, these average correlations could not adequately explain all of low usage. Since we wanted to investigate the possibility of scaling low lifestyles to a wider population, average values were less helpful than the realization that the tier of low users includes significant numbers of households from every demographic category. We established that using little energy, and being too poor to afford more energy services are two different issues that overlap to some extent. We dispelled the notion that energy-frugal consumers were so unlike the rest of the population that more typical consumers would never be able to emulate their behavior. Since there was no demographic niche that did not contain at least some very low energy households, there was no obvious barrier to replicating low usage across a broader population.

If we are to achieve the very significant reductions in greenhouse gas emissions now under discussion, we need more effective ways to persuade a broad audience that future goals are feasible rather than forbidding. Official suggestions about how to reduce energy consumption are wary about how far the public can be encouraged to diverge from what is considered normal practice. This assumption that current average consumption represents what is "normal" or "natural" conveys the discouraging message that diverging from the norm would be would be difficult to accomplish without duress. Our findings suggest downplaying the normal or typical, in favor of more attention to heterogeneity, and in particular to the low end of energy consumption. Most of the low users in our study were able to redefine what is normal or natural without living in discomfort or deprivation.

Neiman (1989) suggested creating a more participatory energy future by enrolling the public as co-producers of policy. We too support peer-to-peer outreach as a more effective model for information transfer than dissemination from experts to the public. It seemed that for many of our respondents the pursuit of low energy consumption began with a sense of engagement and enthusiasm, while the specific techniques or devices followed. If enthusiasm is a key determinant, then replicating this quality is best accomplished via the narratives of people similar to the target audience segment. Stories from "relatable peers," featuring the type of anecdotes and experiments that we heard, would surely be more compelling than a master checklist. Indeed, if the hallmark of conscious, deliberate low users is a sense of agency and mastery, then the top-down outreach model could actually be counterproductive, in that it privileges expert knowledge instead of encouraging DIY experimentation. A richer understanding of the diversity of low use pathways could lead to more meaningful public participation in solutions to climate change.

Acknowledgements The authors thank the California Air Resources Board for their support.

Funding information The research for this study was funded by California Air Resources Board Contract # 09–326.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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