Energy Equity, Agency, and Distributed Energy Intelligence

Karen Ehrhardt-Martinez, Human Dimensions Research

ABSTRACT

Will the utility of the future drive greater energy equity or greater energy inequities among utility customers? The answer depends on utilities' abililty to successfully integrate all customers into a distributed energy system. While the utility of the future is often defined in technological terms as one that applies information and communications technologies (ICT) and distributed energy technologies to create a smart and decentralized electricity network, this definition often overlooks the increasingly important role of utility customers as essential actors. In order to successfully fill their new role as energy producers, consumers, and managers, the role of customers must continue to transform, ensuring that customers are more informed and engaged. In fact, addressing customers' new needs, desires, and expectations will be key for avoiding industry disruption and maintaining reliability. Who will be the winners and losers of this transition, and what can utilities do to ensure that it doesn't result in greater energy inequities?

This paper draws from recent program implementation experience, utility equity studies, social science research, and some recent, innovative engagement strategies to document the equitability of utility programs today and the likely impact of distributed energy technologies on the energy divide. It briefly discusses the concepts of energy literacy and "agency" and their relevance in shaping the equitable distribution of program benefits. Finally, it suggests that energy inequities will continue to deepen unless utilities proactively work to enhance energy literacy, increase agency, intentionally target priority customers and communities, and leverage collective action.

Introduction

The utility of the future is often defined in technological terms as one that applies information and communications technologies (ICT) and distributed energy technologies (including flexible demand, distributed generation, energy storage, and advanced power electronics and control devices) to create a smart and decentralized electricity network. But where and how do utility customers fit into this equation and what is the likely impact of this transformation on energy equity? Namely, will the utility of the future drive greater energy equity or greater energy inequities among customers? How important is the agency of customers in shaping the success of electrification, decarbonization and flexible load management outcomes? And what actions might utilities take to enhance the agency of customers, promote greater equity, and achieve utility end goals?

This paper will draw from recent program implementation experience, utility equity studies, social science research, and some recent, innovative engagement strategies to document the equitability of utility programs today and the impact of distributed energy technologies on widening the energy divide. It will also discuss the concept of "agency" and its relevance in shaping the equitability of the distribution of consumer benefits. Finally, it will describe opportunities for utilities to enhance energy literacy and customers' sense of agency while taking steps to enhance energy equity and design a more equitable energy future.

Energy Equity and the Equity Landscape

The current energy equity landscape – a reflection of past energy policies and programs as well as income inequality, past environmental injustices, and the varied condition of housing stock – can be characterized as one that is wrought with energy inequities. Although it has been argued that access to energy is a basic human need or right and while many utilities have invested in programs designed to make energy and energy-efficiency more affordable and accessible, recent research clearly shows that these efforts continue to fall short. Across the nation, 25% of households face high energy burdens (where household energy costs are greater than 6% of annual income) and 13% face severe energy burdens (where energy costs are greater than 10% of household annual income). In total, approximately 30.6 million U.S. households experience high or severe energy burdens (Drahobl et al. 2020).

Energy burdens and energy inequities also reflect socio-economic disparities. For example, while the median national energy burden is 3.1% of household income, the median burden for low-income households is more than twice the national median at 8.1%. And even though income is an important factor contributing to high energy burdens, the effects of income are compounded by other factors including age, disability, race, home ownership/tenancy, and home characteristics. According to Drahobl et al. (2020), some of the most highly energy burdened groups are low-income households with older adults, low- income households with disabilities, and low-income households with children under 6 years old (9.3%, 8.7% and 7.1% median energy burden, respectively). Low-income residents living in multi-family housing and manufactured homes also experience higher median energy burdens (5.6% and 5.3%, respectively), while Native Americans, African-Americans, and Latino/Hispanic households experience higher median energy burdens than Euro-Americans or whites (4.2%, 4.1%, 3.5% and 2.8%, respectively.)

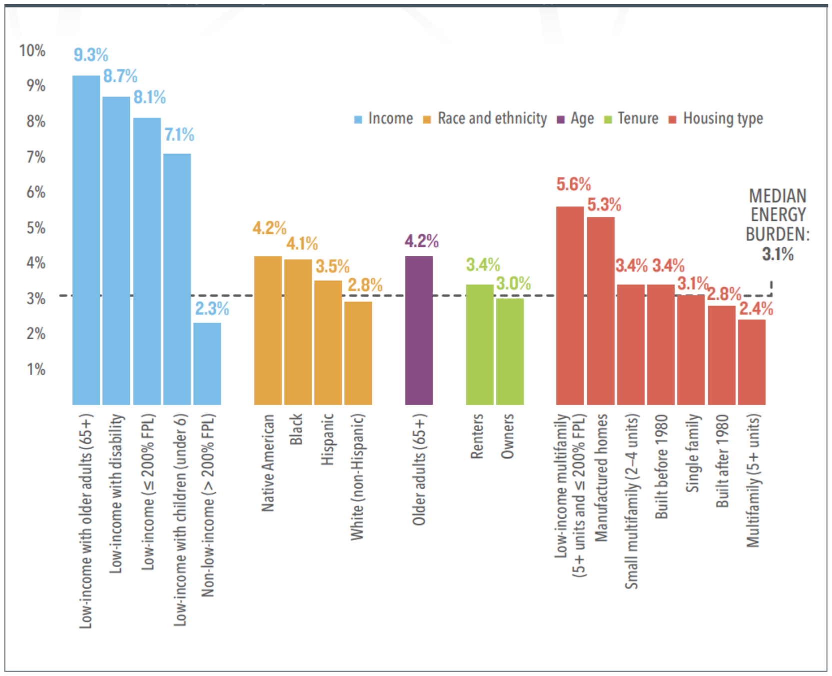

Figure 1: National energy burdens across subgroups (i.e., income, race and ethnicity, age, tenure, and housing type) compared to the national median energy burden. *Source*: Drahobl et al. 2020

Energy burdens also vary regionally. In some areas of the country, more than one-third of all households struggle with *high* energy burdens while one-fifth (20%) struggle with *severe* energy burdens (Drehobl et al. 2020). Of particular note is the East South Central Census division of the Southern Census region comprised of Kentucky, Tennessee, Mississippi and Alabama. This is where the regional median energy burden is the highest in the nation (4.4% versus 3.1%) and approximately 38% of all households struggle with high energy burdens. In this Census division high energy burdens are borne by 74% of all low-income households and 51% of all African-American households. The median energy burdens of these two groups are 2.1 and 1.5 times the median regional energy burden, respectively. In fact, the median regional energy burdens of African-Americans are consistently higher than for Euro-Americans in all nine of the Census Bureau's geographic divisions and are as high as 1.5 times those of Euro-Americans in 4 of the 9 Census divisions (East North Central, the East South Central, the Pacific, and the West South Central). Latinx households also face disproportionately high burdens. The energy burdens of Latinx households are higher than for Euro-Americans in 8 of the 9 Census divisions and are at least 1.3 times those of Euro-Americans in the Mid-Atlantic, Mountain West, Northeast, Pacific, and West South Central Divisions. These regional patterns provide evidence that race-based differences in energy burdens are more pronounced in some areas of the country than others as shown in the table below. Similarly, median energy burdens for low-income households and senior households are consistently higher than those for households as a whole and the differences are especially pronounced in the Mid-Atlantic, Northeast, Pacific, and South Atlantic.

Given the growing attention to socio-economic and regional disparities in household energy burdens across the U.S. and historical efforts by utilities to make energy efficiency programs available to all utility customers (and especially vulnerable customers), some utilities have begun work to determine how successful existing utility programs have been at reaching more highly burdened customers as well as customers who fall into more highly vulnerable socio-demographic groups. In the next section, the paper discusses the findings from this equity research.

The Equitability of Utility Programs Today

Utility energy efficiency programs are designed to encourage utility customers to purchase a range of more energy efficient technologies for their homes with the goal of reducing energy waste in the residential sector. Most utility program portfolios include both market-rate and non-market-rate programs. Market-rate programs tend to be available to all utility customers on a first-come-first-serve basis and typically provide both useful information as well as financial rebates for customers as a means of influencing customers' technology choices and offsetting the cost of purchasing more energy efficient equipment. Non-market-rate utility programs have historically focused on providing energy-efficient equipment to low-income customers. These programs also tend to provide help on a first-come-first-serve basis but require customers to meet income eligibility criteria. Given that most low-income programs cover the full cost of energy-efficiency upgrades for qualified customers, these programs are often limited in the number of customers who can be served each year as a function of limited budget allocations, the cost of efficiency measures and contractor fees, and the energy savings targets set by utility commissions. Although income-eligible customers also have the option of participating in market-rate programs (creating a broader set of potential program participation options for low-income customers), in reality they are often hamstrung in their ability to participate due to their low level of income. As a result, utility programs typically serve a much larger number of customers who are better off financially and a smaller number of low-income customers. These differences in participation are largely rooted in historical program design decisions, funding allocation choices, and social and cultural factors that constrain participation by customers with the greatest needs. This paper sets out to quantify how equitably or inequitably utility programs are reaching different types of customers and recommend strategies for achieving greater equitability in energy efficiency and smart energy programs.

Our evaluation of equity considers three dimensions of utility programs: participation, energy savings benefits, and incentive benefits. For each, we examine the degree to which particular segments of the population are participating in and benefitting from individual utility programs and from the portfolio of programs as a whole. We use data from Experian and the utility to identify vulnerable households, such as those with a low levels of household income (<200% federal poverty line), high energy burdens, being a senior or renter, or being part of a population segment that is characterized as facing multiple socio-economic challenges[1]. We then create a set of indices to measure the proportion of participation and program benefits associated with each of the vulnerable population segments of interest.

For example, if low-income customers represent 20 percent of all customers and 20 percent of all program participants, they would be at parity for participation (20% of participants / 20% of customers = a parity score of 1). If they represent 15 percent of program participants, they would be below parity (15%/20% = a parity score of 0.75). It is our contention that, in combination with an equity goal, parity can serve as a metric for determining degrees of equitability at the program level as a means of helping utility program managers become more intentional about which types of customers are being serving, and it can be used at the portfolio-level to determine the combined impact of all utility efficiency programs. Ensuring parity for vulnerable or marginalized segments could serve as a minimum standard for portfolio-level equity with some utilities opting to ensure a higher proportion of benefits reach vulnerable households.

Over the past 2 years, we applied this approach in work with four large investor-owned utilities. The program and portfolio-level equity findings from these studies are summarized below:

Equity Findings for Utility Programs

- As intended, *low-income or income-eligible programs* tend to be successful at reaching a disproportionately large share of low-income households and households with high energy burdens, and these customers also receive a large proportion of both energy savings benefits and incentive dollars.
- *Market-rate programs* are only somewhat successful at reaching low-income or highly burdened customers, particularly when these programs have large upfront costs. Some low-income customers and some highly burdened customers do participate but they participate at very disproportionately low rates. (For example, participation in refrigerator recycling programs (which have no upfront costs) is close to parity for low-income customers but disproportionately low for highly burdened customers.)
- The program-level results for *multi-family customers* and renters are mixed with some low-income programs achieving inclusion rates above parity for renters while multi-family customers are consistently and strongly underrepresented.

[11] We use Experian's MOSAIC segments as a means of segmenting customers into 19 groups according to multiple socio-demographic characteristics. (mosaic-usa.pdf (experian.com) Among these, 7 segments were determined to be more vulnerable due to lower levels of income, education, language, etc. We also tracked customers who were not classified by Experian as "unknowns" or "unclassified" to determine how well they were being served by utility programs.

- *Disadvantaged MOSAIC segments* tend to follow the overall trends found for low-income customers such that participation rates and benefits for disadvantaged customers tend to be well above parity. Results for "*unclassified segments* (those customers for whom there is insufficient information to assign them to a specific MOSAIC segment – also known as "Unknowns") show a strong tendency for these customers to fare the worst when it comes to program inclusion and benefits.
- Notably, *the most advantaged MOSAIC segments* have a disproportionally high inclusion score for market-rate programs, often participating at 200% of their representation in the customer base.

Equity Findings at the Portfolio Level

- At the portfolio level, *low-income and highly burdened customers* participate at, or slightly above, parity and receive a disproportionately high level of incentive benefits.
- *Multifamily customers, renters, and rural customers* are consistently underrepresented at the portfolio level and reap a disproportionately small share of program benefits.
- Customers in *disadvantaged MOSAIC segments* are proportionally represented among program participants at the portfolio level and receive a disproportionately high share of energy savings and incentive benefits.
- Customers in "*unclassified" MOSAIC segments* fare the worst, being consistently and dramatically underserved by utility programs with inclusion scores between 0.15 and 0.20.
- The *most advantaged MOSAIC segments* tend to participate at disproportionately high rates and receive the most disproportionately high share of energy savings benefits but a proportional share of incentive benefits.

What do all these equity metrics tell us? At the program level, they tell us that market-rate and non-market-rate programs are largely serving the types of customers that they were designed to serve. Traditional, market-rate programs tend to disproportionately serve customers who are more advantaged, although some market-rate programs reach other segments of customers as well. Market-rate programs also reach the largest volume of customers, however the incentive benefits for individual participants are modest. particularly when these programs have large upfront costs. Low-income programs successfully reach a disproportionately large share of low-income customers, those with high energy burdens, and those in disadvantaged MOSAIC segments, and these same customers reap a disproportionately large share of energy savings and incentive benefits. Interestingly, however, it is the households that haven't been classified into MOSAIC lifestyle segments that fare the worst in terms of both program inclusion and benefits, receiving a disproportionately low share. Multi-family customers are also among those that are consistently underserved.

At the portfolio level, low-income and highly burdened customers are participating at or near parity – indicating that their participation is on par with their representation in the population. Even though participation doesn't always reach parity at the portfolio level, lo-income and highly burdened customers do receive a disproportionately large share of program benefits given that the incentives provided through income-eligible programs typically cover the full cost of participation. Customers in disadvantaged MOSAIC lifestyle segments were also found to have inclusion scores near parity. On the other hand, multi-family customers, renters, and rural customers were found to have disproportionately low inclusion scores and failed to receive a proportional share of program benefits. These results indicate that utility programs have achieved some success at reaching vulnerable customers. Nevertheless, some types of vulnerable customers are underserved. In addition, some types of vulnerable customers (the unclassified) were revealed to be grossly underserved which is likely due to program designs that fail to prioritize the vulnerable customers with the greatest needs. And finally, it is important to note that the results of this analysis fail to answer the question as to whether achieving parity should be construed as achieving equity or whether a different definition of equity should be applied – a definition that is grounded more firmly on prioritizing customers with the greatest need rather than incenting customers who are likely to adopt more efficient technologies without financial incentives.

The Energy Efficiency, Smart Technology Divide

As mentioned in the introduction to this paper, smart technologies are integral to our conception of the utility of the future – one that is focused on the application of information and communications technologies (ICT), energy storage, advanced power electronics and control devices as a means of orchestrating flexible demand and distributed generation and achieving a clean energy future. In the future, many of these ICT technologies will be present in people's homes and vehicles and will necessitate some level of collaboration between utilities (and/or other entities) and households to employ those technologies to manage energy use and maintain grid reliability. The implication of the envisioned transition to a clen energy future is a changing role for utility customers and the need for a higher level of customer engagement, calling into question whether *all* customers will have the opportunity to participate in and benefit from the changing energy system in the same or similar ways and/or whether the benefits of energy efficiency, electrification, and flexible load management are likely to be limited to a subset of customers resulting in a broadening of existing energy inequities. What might we learn from existing studies on the digital divide between more and less affluent consumers or other marginalized groups?

According to a recent PEW study (2021), internet use, broadband adoption and smartphone ownership have grown rapidly for all Americans, howevert there is still a marked difference between the digital lives of Americans with lower and higher incomes. These differences are most pronounced for computers, tablets, and broadband but less notable for smartphones as shown below. While 63 percent of households with higher incomes are likely to have multiple devices at home, 13% of adults in households with incomes below $30,000 a year do not have access to *any* of these technologies. Of those who do, they are much more likely to rely on smartphones, with 27% of adults in low-income households relying exclusively on smartphones for internet access.

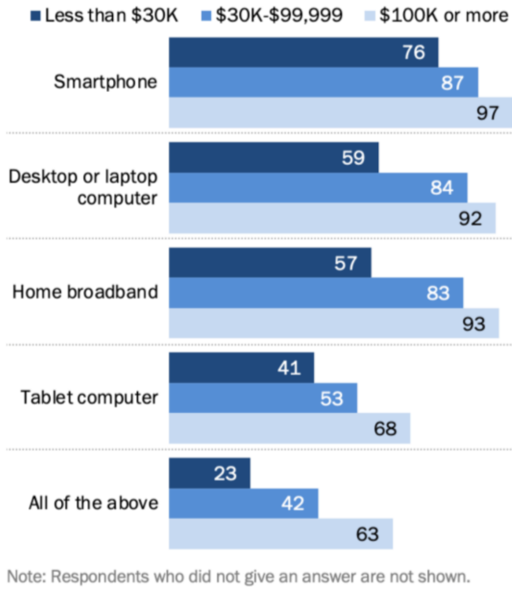

Figure 3: Percent of U.S. adults who say they have each of the following, by household income. *Source*: PEW 2021

A recent HUD report on digital inequality and low-income households also documents the persistent divide in the distribution of ICT resources across households. According to the report, digital inequality has come to both reflect and contribute to other persistent forms of social inequality.

> *Disparate access to the Internet and digital devices corresponds closely with longstanding inequalities in income, education, race and ethnicity, age, immigration status, and geography. At the same time, the negative consequences of being underconnected are growing, and researchers and policymakers are increasingly concerned that underconnection is fueling other socioeconomic disparities* (HUD 2016).

The good news is that digital penetration in the U.S. increased dramatically between 2000 and 2012. Whereas only 1 in 4 U.S. families had internet service in 2000, three-quarters had access in 2012. Nevertheless, more recent studies have broadened the discussion to better understand the complex ways in which digital access varies. Newer studies focus on both 1) the multidimensionality of digital inequality and 2) multilevel digital inequalities. Among the multidimensionality concerns are:

- Questions about how variations in the technology used to access the internet impact the ease or difficulty of gaining access.
- Questions about how autonomy of internet use varies, underscoring the importance of in-home Internet access.
- Questions concerning variations in skill levels that people bring to their Internet use, highlighting the importance of "digital literacy" – "those with greater skills are more confident and less hesitant about finding trusted information online and are better able to take advantage of emerging technologies."
- Questions about variations in sources of social support that can provide technical assistance.
- Questions about variations in the reasons that people use the technology.

Multilevel Digital inequalities also highlight how "social dynamics at different levels of society influence Internet access and use" and consider how family, community, neighborhood and network factors contribute to digital inequalities. This is illustrated in the following table which highlights the variation in access to in-home high-speed internet and device ownership across different housing characteristics.

According to the HUD report, solutions to these digital access challenges will require a multi-pronged approach that addresses the affordability of devices and broadband access, digital literacy training, and publicly accessible computing centers with helpful staff and support. In the meantime, the ongoing digital divide will serve as a significant barrier to the adoption of the wifi-enabled technologies and systems that are needed for an inclusive and equitable development of a clean energy future and will likely widen the energy-efficiency gap as well as the gaps in renewable energy, flexible load management, and decarbonization.

The smart-technology divide further exacerbates the gaps in utility program participation and efficiency benefits illustrated earlier in this paper. Even though utility program portfolios are serving more vulnerable customers at or near parity, the programs tend to be focused exclusively on enhancing energy efficiency in ways that generally do not involve smart technologies often because customers lack wifi at home. These choices preclude vulnerable customers from fully participating in the smart energy transition.

Table 1. In-Home High-Speed Internet Subscription and Device Ownership Among U.S. Households by HUD Subsidy

Housing Characteristics	Percentage with high-speed Internet subscription[1]	Percentage with desktop or laptop computer[2]	Percentage with hand-held computer only[3]
Total Households	75.1	78.1	6.5
HUD-Assisted Renters	43.1	44.2	14.1
Public Housing	40.8	41.0	14.4
Voucher	49.1	51.0	15.1
Multifamily	35.6	36.3	12.4
Unassisted Renters	69.0	71.7	10.6
Owners	80.2	83.6	3.9

[1] Does not include those who use the Internet without a paid subscription. High-speed Internet indicates that a household has Internet service other than dial-up.
[2] Includes households that own or use a desktop, laptop, netbook, or notebook computer at their home.
[3] Includes households that own or use only a handheld computer, smart mobile phone, or other handheld wireless computer at their home.
Source: U.S. Census Bureau and U.S. Department of Housing and Urban Development. "2014 American Community Survey and HUD Administrative Data (PIC, TRACS, HUD-951)."

Energy Literacy and the Push toward Electrification, Decarbonization and Flexible Load Management

As utilities are increasingly concerned with whether, when, and how their customers use energy, energy literacy will play a more pronounced role in achieving a clean energy future. Energy literacy can be defined in a variety of ways. In one recent article Van den Broek (2019) defines energy literacy in practical terms focused on knowledge about 1) the energy consumption of domestic appliances, 2) what actions can save energy in the home, 3) how to make economic energy efficient decisions, or 4) understand the relationship between energy use and climate change. This definition involves a multifaceted typology of energy literacy focused on device efficiency, financial impacts, and broader environmental dynamics between energy production and consumption.

Martins et al. (2019) look at energy literacy in a slightly different way by focusing on a combination of cognitive understanding, sentiments, and behaviors. Cognitive understanding encompasses energy knowledge, understanding and skills. Conversely, the concern with sentiments is focused on a variety of feelings and sentiments, including customer attitudes and sensibility. Finally, the focus on behaviors includes an understanding of customers' intentions, involvement and actions. In their paper, Martins et al. (20119) also expand prior conceptions of knowledge and argue that the "knowledge needed to make informed energy-related decisions, can not only include the knowledge about energy, but will have to include some basic financial concepts, that give people the necessary skills to perform financial calculations."

Finally, in their discussion of time-differentiated rates, Reis et al. (2021) offer a third perspective on energy literacy that is concerned with 1) an individual's proficiency on energy-related topics, 2) numeracy, and 3) graphical literacy. They also consider decision styles and the way that electricity rate information is framed in an attempt to understand customers' willingness to adopt time differentiated rates. The results from this study point to energy literacy as a crucial factor in "facilitating the readability and understandability of [time differentiated rate] information and in encouraging end users to adopt [these rates]".

Despite the growing body of evidence linking energy literacy to energy efficiency, and customers' willingness to participate in time differentiated rates, a new report from the National Energy Foundation found a decline in how well teenagers in the U.S. understand a variety of energy topics and how much they engage in energy efficient behaviors (American Public Power Association 2023). According to the study, the average energy literacy score fell from 48.8 to 42.4 between 2017 and 2022 with both scores reflecting a relatively low level of energy literacy. In addition, the survey found that while students know about the importance of the energy transition, they did not have a strong sense of agency. In fact, most students indicated that they do not believe their actions can make a difference. In all, only 31% of students believed that their efforts to conserve energy would have a positive impact on the environment (a 15% decrease), and only 26% felt a moral obligation to reduce their energy use (a 9% decrease). These findings suggest that both energy literacy and a customer's sense of *agency* may play an important role in the successful design of energy-efficiency programs and strategies for successfully engaging with a larger number of households.

But how does *agency* shape energy-related choices and actions? In psychology, "agency" and "self-efficacy" are concepts associated with beliefs held by an individual as to whether or not they can achieve a particular goal or outcome. Survey research by Cotton et al. (2016) studied the relationship between knowledge, agency, and energy-saving behaviors and found evidence that while levels of knowledge did influence behaviors, a sense of self-efficacy or agency was also influential. Their findings showed that having a lower level of income and perceptions of powerlessness had a negative effect on participation in energy-efficiency events.

More recent research has documented the influence of self-efficacy on solar PV adoption (Tanveer et al. 2021). This study hypothesized that "the willingness of consumers to adopt solar PV is positively influenced by [perceived self-efficacy]. The results confirmed that perceptions of self-efficacy had a favorable impact on customer perceptions of solar PV adoption.

Interestingly, the study by Cotton et al. also found that programmatic efforts to address powerlessness can be effective and these efforts may take multiple forms including both formal and informal forms of collective action. Efforts focused on leveraging formal collective action are often focused on working through community groups, nonprofit organizations, utilities, cities and other entities while efforts focused on leveraging informal collective action are more likely to be focused on enhancing customer participation via online social networks or interest groups.

The problems associated with low levels of energy literacy and self-efficacy may in part be rooted in sociocultural differences between program implementors and vulnerable customer groups and manifest are difficult to overcome in an atmosphere of distrust. While these issues and relationships deserve further research, some program implementers have used formal forms of collective action as a means of tackling these problems. Similar techniques could be used to facilitate the adoption of smart energy technologies.

Impact of Distributed Energy Technologies on the Equitability of Our Clean Energy Future

As discussed above, today's energy landscape is one that is best characterized as highly inequitable where energy burdens and energy insecurities are borne at disproportionately high rates for certain segments of the population. National and regional research into the uneven distribution of energy burdens across households clearly shows the dramatically different burdens borne by lower income households, African-Americans, Latinos, seniors, renters, and those living in older housing stock (Drehobl et al. 2020). These inequities are often made worse as a result of market-rate, utility programs given that such programs often serve a greater number of customers from more advantaged population segments while income-qualified programs tend to reach a smaller subset of vulnerable households.

As discussed earlier in this paper, achieving industry goals for a clean energy future will require much needed growth in customer participation and engagement, the adoption of newer and smarter technologies, and an enhanced distribution of energy intelligence that comes from energy literacy and a strong sense of self-efficacy. The evidence shared in this paper suggests that the cards are currently stacked against vulnerable customer segments most of whom are already challenged by the ongoing digital divide and who often face substantial financial barriers and lower levels of energy literacy and self-efficacy. In the face of these challenges, the continuation of the current structure of long-standing utility programs is likely to simply result in an exacerbation of existing energy inequities and forestall the full transition to a clean energy future. The good news is that a variety of potential solutions are available. In addition to the efforts of the Federal Government via their investments via IRA and IIJA dollars, utilities should be strongly encouraged to:

- Identify the segments of customers in the utility's service area who are most vulnerable.
- Develop and track program and portfolio-level equity metrics for vulnerable customer groups.
- Establish a bold set of energy equity goals and objectives that prioritize utility program participation for the most vulnerable customer segments focused on the installation of energy efficient technologies and smart, wifi-enabled technologies, and reduce energy burdens while achieving energy savings (including funding for smart energy technologies) for the most vulnerable customer segments
- Establish new financial approaches and collaborative efforts to expand funding/financing opportunities for low and moderate-income customers (including braided funding, and tariff-based financing for energy efficiency and clean energy technologies and home upgrades).

- Work with utility regulators to reallocate utility program dollars with a goal of allocating a larger proportion of utility program dollars to serve customers with the greatest needs.
- Proactively target the most vulnerable utility customers and communities with marketing and education campaigns instead of relying on vulnerable customers to invest scarce time and resources to learn more.
- Increase investments in energy literacy and leverage formal and informal collective action opportunities through trusted community groups and social media outlets to expand energy literacy and agency, overcome the multiple challenges faced by vulnerable customers, and reduce customers' perceptions of risk associated with participation in utility programs.

Taken together, these seven recommendations could increase the impact of utility programs, reduce energy burdens and energy inequities, and forestall (if not reverse) the widening of the energy efficiency gap in the future by helping vulnerable households and communities to become active participants and partners in a clean energy future.

References

Adams, James; Kenner, Alison; Leone, Briana; Rosenthal, Andrew; Sarao, Morgan and Taeya Boi-Doku. 2022. "What is energy literacy? Responding to vulnerability in Philadelphia's energy ecologies. *Energy Research & Social Science* 91 (2022) 102718. Available at: *What is energy literacy? Responding to vulnerability in Philadelphia's energy ecologies (energyoutreach.org)

American Public Power Association. 2023. "Energy Literacy, Energy Efficiency Behaviors Among Young People Declining." June 20, 2023. Available at: Energy Literacy, Energy Efficiency Behaviors Among Young People Declining | American Public Power Association

Cotton, Debby; Miller, Wendy; Winter, Jennie; Bailey, Ian; and Stephen Sterling. 2016. "Knowledge, agency and collective action as barriers to energy saving behavior." *Local Environment: The International Journal of Justice and Sustainability*. Vol 21(7): 883-897. Available at: Knowledge, agency and collective action as barriers to energy-saving behaviour: Local Environment: Vol 21, No 7 (tandfonline.com)

Drehobl, Ariel; Ross, Lauren; and Roxana Ayala. 2020. "How High Are Household Energy Burdens: An Assessment of National and Metropolitan Burden across the United States." ACEEE: Washington, D.C.

HUD 2016. "Digital Inequality and Low-Income Households." In *Evidence Matters: Transforming Knowledge into Housing and Community Development Policy*. Available at: Digital Inequality and Low-Income Households | HUD USER

Martins, Ana; Madaleno, Mara and Marta Ferreira Días. 2019. "Energy literacy: What is out there to know." *Energy Reports* ICEER2019 – 6th International Conference on Energy and

Environment Research: “Energy and Environment: challenges towards circular economy. Available at: Energy literacy: What is out there to know? - ScienceDirect

PEW. 2021. “Digital divide persists even as Americans with lower incomes make gains in tech adoption.” Emily A. Vogels. PEW Research Center. Available at: Lower-income Americans still less likely to have home broadband, smartphone | Pew Research Center

Reis, Ines F.G.; Lopes, Marta A.R., and Carlos Henggeler Antunes. 2021. “Energy literacy: an overlooked concept to end users’ adoption of time-differentiated tariffs.” *Energy Efficiency*. (April 8, 2021). Available at: Energy literacy: an overlooked concept to end users’ adoption of time-differentiated tariffs | Energy Efficiency (springer.com)

Tanveer, Arifa; Zeng, Shihong; Irfan, Muhammad; and Rui Peng. 2021. “Do Perceived Risk, Perception of Self-Efficacy, and Opennes to Technology Matter for Solar PV Adoption? An Application of the Extended Theory of Planned Behavior.” *Energies* 14:5008. Available at: Tanveer et al Role of Perceived Risk and Self Efficacy on Solar Adoption.pdf

Van den Broek, Karlijn L. 2019. “Household energy literacy: a critical review and a conceptual typology. *Energy Research & Social Science* 57 (November). 101256, https://doi.org/10.1016/j.erss.2019.101256.

Walling, Melina. 2021. “Bridging the Energy Efficiency Divide.” *Forbes*. May 27, 2021. Available at: Bridging The Energy Efficiency Divide (forbes.com)