

Utility Marketplaces Can Improve Energy Efficiency Program Uptake

William Hughes, Guidehouse Insights

ABSTRACT

Many entities offer programs that encourage low and moderate income (LMI) homeowners to upgrade their appliances and weatherize homes to improve energy efficiency. Unfortunately, these programs are often underutilized. Participation varies by region, but the most optimistic estimates are that only a few percent of eligible homeowners take advantage of these programs.

The growing presence of utility marketplaces can help increase adoption. Some advanced marketplace programs collect power usage data from individual homes, evaluate specific opportunities for reducing energy consumption, and present the most effective solution(s) to the homeowner for consideration. These types of marketplace apps show the recommended solution with its list price, but also include any applicable discounts, coupons, or rebates available from the utility, ultimately showing the net price for the product. A powerful extension of this would be to incorporate information about qualification for special grant programs and adjust the pricing information accordingly, and increase the utilization of programs specially designed to support LMI homeowners.

Several vendors that offer advanced marketplace solutions are working with utilities to offer their customers access to such solutions, though case studies are not yet available on their real-world implementation (Oracle 2022) (Bidgely 2022). Using data analysis and targeted marketing, utilities will be able to tell homeowners specifically which of their appliances are least efficient and quantify the financial advantages of upgrading them. The provision of specific information is much more compelling and more likely to encourage adoption than the historic approach of offering generic assistance to address unidentified problems. Through this approach, there is great potential to reduce energy consumption by all utility customers, including LMI homeowners.

Introduction

Americans have a great deal of autonomy on how they use power, within the limits of their home's electrical infrastructure. For most, the strongest motivators for minimizing their energy use are the desire to lower their energy bill and the desire to protect the environment (Yale 2021). For many, this involves navigating the financial tradeoff faced when considering upgrading a costly but inefficient appliance. For example, replacing an old, but functional, oil furnace with a heat pump is both costly and disruptive. For many, the investment is not compelling until the old appliance fails. Utilities and public agencies offer financial incentives to motivate homeowners to make the investment a priority. These can be adequate for homeowners that are not under financial stress. However, low to moderate income (LMI) customers are typically not in a position to replace older appliances and heating, ventilation, and air conditioning (HVAC) equipment until they fail and require replacement. This puts many people in a place of energy insecurity.

Fortunately, there are many programs to support residents in this situation. The challenge is that many useful programs do not get fully utilized. Any given homeowner has so many energy efficiency (EE) investment options with a range of conditions that many useful programs do not get fully utilized. Emerging technology holds the promise of being able to narrowly target different customer segments based on their energy use and financial situation, which can be leveraged to encourage participation in programs targeting LMI utility customers.

This new technology is based upon energy usage data from advanced meters communicated over the advanced meter infrastructure back to the utility. It is then provided to a disaggregation application, run on behalf of the utility, to discern usage patterns. This information, combined with payment history, demographic information, and public databases such as building permits, creates the opportunity to increase the effectiveness of solutions and financing options offered to customers to ultimately increase energy efficiency and reduce carbon emissions to those for whom it would be most effective.

Residential LMI Energy Efficiency Programs

Homeowners with limited means to invest in EE programs face a circular problem, since return on investment takes place over time. They do not have the ability to pay the up-front costs to reduce their energy bills. Their home's problems, such as failing appliances, poor windows, or a damaged building envelope continue to deteriorate and energy bills tend to increase, further reducing their ability to invest in upgrades. Numerous regional level and state level programs have been developed to address this problem. While these programs primarily provide financial assistance to LMI households, some provide financial incentives to improve the energy efficiency of their residences.

Regional Programs

The electrical power industry has worked for many decades to limit the need for additional generation capacity by improving energy efficiency (Edison 2018). When successful, these efforts help mitigate the environmental impact of energy generation and avoid the need for costly capital improvements. Many organizations, ranging from large generation entities to regional regulatory bodies, have offered ratepayers within their jurisdiction a variety of programs to encourage and accelerate the adoption of more energy-efficient building technologies.

For an example of a typical program, the Bonneville Power Administration (BPA), based in Portland, OR offers rebates to the customers of the individual utilities with whom it contracts its power when they install qualified efficient equipment (Bonneville 2022). The utilities offer this service to their ratepayers, collaborate with their trade allies where appropriate, and track the acquisition and installation of equipment on the approved list. Most parts of the US have similar programs that may be offered by states or regional Independent Service Operators (ISO).

Federally supported programs

There are also several Federally funded programs that offer homeowners support for energy efficiency upgrades. The primary examples include:

- **Low Income Home Energy Assistance Program (LIHEAP):** Established in 1981, the US Department of Health and Human Services operates this program. Block grants are

given to states, who then have some discretion on how they provide low-income residents assistance with winter energy bills and sometimes for cooling bills. (DHHS 2022)

- **Weatherization Assistance Program (WAP):** The WAP program was created by the US Department of Energy in 1976 to help low-income homeowners. Again, states have discretion on how the program is implemented within their state, but they typically involve in-home inspections to make recommendations regarding the priority of projects that will reduce energy consumption. Private contractors complete the work and submit the appropriate paperwork. While they operate under separate Federal agencies, the LIHEAP and WAP programs tend to collaborate at the state level. (DOE 2022)
- **Residential Property Assessed Clean Energy Programs (R-PACE):** Also run by the Department of Energy, this program enables a property owner to finance the up-front cost of energy efficiency investments or other eligible improvements to a property and then pay the costs back over time through a voluntary assessment. Eligible improvements include replacement of HVAC equipment and water heaters, as well as the purchase of Energy Star certified appliances and solar panels. (DOE 2022)

Challenges faced by these Federal and regional programs

These programs have a decades-long history of making important contributions to reducing energy demand and assisting many households that face energy insecurity (NASCP 2022). Despite their successes, however, these programs face several challenges, including:

- **The source of funding is limited:** Some programs, particularly the Federal programs, have a limited budget with very little flexibility. When the fixed budget is spent, the program ends. This could occur early in the fiscal year or there may still be unspent funds at the end of the fiscal year. This creates uncertainty for applicants as to whether applying is a worthwhile investment of time.
- **The process can be intrusive:** The applicant must share detailed personal and financial information and the application process sometimes involves an inspection of the residence by an agent of the government. While some states can authorize eligibility for the LIHEAP and WAP programs when the individual qualifies for other programs, this practice is not universal.
- **Qualifications vary significantly by area:** Each state has latitude in determining how it implements the block grant programs within the guidelines set forth by the respective Federal agencies. The implementation of rebate programs varies by utility. The result is that an applicant's experience with these offerings may differ greatly from the experiences of their friends and family members, creating confusion and hesitation.
- **The programs do not target the households that are least efficient:** These programs are open on a first-come/first served basis, as long as applicants meet the income criteria. The energy consumption/efficiency of the home is not considered. A household that could gain only modest improvements that applies earlier in the fiscal year has priority over a household with a home in need of significant improvements that applies later in the fiscal year.

- **Confusion over the implication of homeownership:** Many government support programs consider the net worth of the individual in addition to net income when considering eligibility. However, LIHEAP, WAP, and R-PACE only consider income and not, for example, the value of equity in the home. This can create confusion. According to the US Census Bureau, there are over six million households with income under \$20,000 annually that also own their home.
- **The program relies on the individual to take the initiative:** Friends, family, and local agencies may encourage a homeowner to apply to one of the programs, but the effort is ultimately up to the homeowner.

Despite the generosity of these programs along with the successful track records in serving individuals and increasing energy efficiency, uptake has been relatively modest (Fowle 2015). To put this in perspective, Figure 1 shows the percentage of households that reported taking some action that relates to energy insecurity, such as foregoing food or medicine to pay their electricity bill.

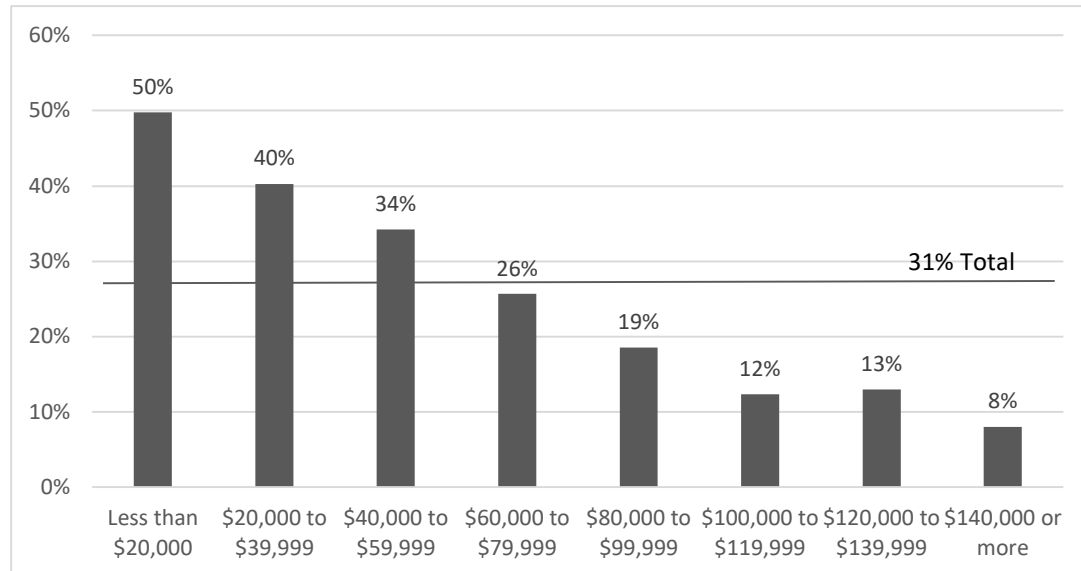


Figure 1. Percentage of Households Reporting Energy Insecurity
(Source: Energy Information Association, Department of Energy, RECS study Table HC2.5)

As might be expected, households in the lowest income category are most likely to have experienced energy insecurity in the past year. Energy insecurity includes reducing food or medicine to pay for energy, receiving a disconnection notice, or setting the temperature at an unhealthy level. An overall average of just over 31% of US households, including people of all income levels, experienced energy insecurity.

The same survey asked the same respondents about their use of energy related benefits. Table 1 shows the uptake of available benefits for the lowest income bracket and the rest of the income brackets.

Table 1. Energy-related benefits received by homeowners (more than one may apply)

Available Benefits	Percentages of residences with income of less than \$20k using this benefit	Percentage of all other residences using this benefit
Energy-efficient light bulbs	3.5%	4.9%
Home energy audit	1.7%	1.9%
Rebate for new appliance or equip.	1.3%	4.1%
Recycling old appliance or equip.	2.2%	6.3%

(Source: Energy Information Associate, Department of Energy, RECS study Table HC2.5)

These results reveal several important issues. First, presence of financial stress associated with energy insecurity does not seem to lead homeowners to take advantage of programs that are in place to alleviate that stress. Second, the homeowners that do use these services are not necessarily the most in need of support or are those for whom the support would have the most impact. People in the lowest income bracket, who experience the highest amount of insecurity, are less likely to use any of the available programs than those with higher incomes.

This situation is consistent with other studies. A study performed by The National Bureau of Economic Research report, “Do Energy Efficiency Investments Deliver?” found that only 1% of eligible homeowners took advantage of the WAP program. They commissioned a comprehensive promotion program to educate and motivate eligible homeowners to apply for this benefit. The result was that 6% of eligible homeowners applied. These results can be interpreted in starkly contrasting ways. On one hand, this promotional effort increased usage by a factor of six. On the other hand, despite extensive outreach efforts, more than 94% of homeowners were hesitant to participate in programs offering improved energy efficiency and reduced energy bills at no charge.

Low participation is clearly a major problem for these programs. This presents a meaningful opportunity to improve their effectiveness. These programs were instituted decades ago and several recent technological innovations have the potential to increase their effectiveness. These changes involve a combination of disaggregation applications, remote energy audits, and utility marketplace applications.

Disaggregation-based Technology Solutions to Support EE Adoption

Historically, the utilities’ market segmentation has been coarse, identifying broad groups, such as residential or commercial & industrial (C&I) customers. Users could be further segmented based on the magnitude of their monthly usage and their payment method and history. While this level of customer segmentation can be somewhat useful, only very limited insights into the ways that customers use electricity within their home, the challenges they face with energy insecurity, and their propensity to take steps to reduce that insecurity or reduce their environmental impact can be gleaned.

Several technological innovations in recent years have enabled utilities to infer more detailed information about the usage of different electrical loads within a home. Depending upon the context, this may be called “disaggregation,” but is also called non-intrusive load monitoring (NILM). Both terms refer to the collection of data on power usage at a residence and the transmission of this information to a disaggregation engine in the cloud for analysis. To

successfully implement an advanced marketplace that can serve LMI customers, two elements are needed: home monitoring and disaggregation applications.

Home Monitoring Options

There are two options for collecting energy usage information from a home. The first is the collection of data from advanced meters. Unlike traditional electric meters that require periodic visits from a utility representative to read the meter, advanced meters with the advanced meter infrastructure (AMI) can transmit usage data back to the utility wirelessly. The transmissions needed for billing requires only one monthly transmission. Modern AMI systems send data from each meter as frequently as every fifteen minutes, or even five minutes. This amount of data is sufficient to enable disaggregation.

There are also purpose-built devices that can be installed at a residence, often by the homeowner, that duplicate the functions of a regular power meter, but can also send usage data over the internet to a cloud application. Trials are underway in California and Michigan. Some of the more basic home-based monitors measure the electrical current entering the house and send that information over the home's Wi-Fi network to the cloud. More sophisticated home-based monitors have more capabilities and options. Some include sensors, either called AC current clamps or Rogowski coils, that monitor the power used by individual circuits coming out of the home's central electrical panel.

These devices typically measure larger loads, like an oven, an HVAC system, and a washer/dryer, although they can work on any circuit. The more sophisticated home-based monitors also have more communications options that can send the usage data over a smart home wireless network to ultimately get to the cloud. These types of home-based monitors collect much more detailed information on power usage within the home, such as power transients and short-term power draws associated with specific appliances, but also involve more complicated installation and must be connected to the home's electrical wiring.

Disaggregation Applications

After the energy usage data from the home is sent to the disaggregation app in the cloud, sophisticated machine learning algorithms are able to infer the usage of loads within the home by identifying patterns and leveraging historical data. Historical data embedded in these algorithms include power usage data on individual appliances and other electrical loads, time of use data, and local weather conditions. Some patterns are easier to discern than others. Ovens and cooktops tend to be used at mealtimes. Refrigerators cycle on more frequently during mealtimes, but otherwise in a predictable pattern when left unopened. Lights go on when it is dark outside and rooftop solar panels generate power when daylight is available. Over time, and with enough verified usage information, a disaggregation application can accurately discern the actual usage patterns 90% to 95% of the time (Oracle 2022) (Bidgely 2022) (Powerley 2022).

The outputs of these models offer detailed insight into the energy use patterns within a household. There are three levels of information that disaggregation can discern:

- **Macro changes:** These include the acquisition or exchange of major appliances, the addition of distributed energy resources such as roof-mounted solar panels, or the acquisition of an electric vehicle being charged at home.

- **Operational patterns:** This category includes the frequency of usage of different appliances and loads, such as identifying the usage of space heating, ovens, dishwashers, washer/dryers, and lighting. With higher resolution information, a disaggregation application can discern details, such as the number of loads run in a washing machine or dishwasher and the usage patterns of microwaves and conventional ovens.
- **Subtle changes:** With validated high-resolution information, a disaggregation application can identify smaller, but important, changes in the behavior patterns of the electric load. For example, it can discern when a central air conditioning system is taking longer to cool a home. The cause for such a situation could be filters in need of replacement, the loss of refrigerant, or a failing compressor.

Identification of Macro Changes

Though the identification of some macro changes may seem obvious from simple energy usage patterns, there are typically many possible causes for changes in usage. For instance, an EV charged at home typically results in an increase in power usage by 20% or more, but a simple increase of that magnitude does not necessarily mean that a household acquired an EV. A sudden increase in usage could be attributed to any number of changes, such as an increase in the number of residents within the home or extreme weather conditions. However, if the timing of the load tends to be consistently in the evening or overnight, there is a greater likelihood that the added usage is the result of a newly acquired EV.

It is important for a utility to have the information on the presence of EVs to be able to prepare for its impact on the grid. There is also the potential for the utility to offer the homeowner special pricing or a demand response program that encourages the user to charge during off-peak times. Knowledge of the presence of an EV will often cause a utility to communicate with a customer regarding these issues.

However, inappropriately concluding that a household acquired an EV would be problematic if the sudden increase in usage was from another cause, such as an increase in the number of people living at the residence because of financial distress. In this scenario, the non-EV-owning customers would be sent irrelevant information on what can be perceived as a luxury purchase when information on support for replacing old, inefficient equipment appliances would likely be more helpful. This is an example in which narrowly targeting customers with detailed information is important.

Identification of Operational Patterns

Residential operational patterns offer insight into the ways that different people use electricity. This includes accurate estimates of the amount of electricity used for lighting and the mix of bulb types, the usage of cooking appliances, HVAC, water heating, EV charging, DER generation, and home entertainment.

Within certain ranges, a disaggregation application can also identify changes in usage. This could indicate the replacement of appliances or equipment or a change in usage patterns. For example, the installation of a sophisticated thermostat can be inferred from its operational patterns even when the performance of the heating and cooling equipment is unchanged.

The Ability to Identify Subtle Changes

Current state-of-the-art disaggregation applications are very effective at identifying macro changes and reasonably accurate when identifying operational patterns across a range of uses. The next level of performance, which is actively being developed by the companies that offer disaggregation, involves the ability to discern subtle changes in energy use based on increasingly granular data. This involves more frequent sampling of energy usage within the house, homeowners providing specific make and model numbers of their appliances, and the integration of local weather information. Some of the capabilities under development include:

- **Changes in performance:** The disaggregation application can identify when the performance of a piece of equipment is degrading. This could be because of a lack of maintenance or impending component failure. It could also be the result of natural aging or preferences of a resident within the home. The aggregation application can learn, over time, to predict which behavior is most likely.
- **Increased loads due to poor insulation and air infiltration:** Indoor heating and cooling is the single largest use of electricity within most homes (EIA 2022). A lack of adequate insulation is an ongoing problem. The amount of thermal loss from air infiltration can vary over time. A disaggregation application can consider performance characteristics of the heating and cooling system, along with the local weather conditions, to discern the problem.

The ability of a disaggregation application to accurately discern the precise health status of each appliance increases as the resolution of the load data increases and as it builds its statistical base and is verified by actual performance. Over time, the accuracy of the disaggregation application improves. Today, the most basic disaggregation applications can discern macro changes and are reasonably effective at identifying operational usage. Within the next several years, disaggregation technology will improve and be able to discern subtle changes in the operation of loads at the residence.

Privacy Considerations

The capabilities of disaggregation applications raise concern about the privacy and security of the information collected and generated. After concerns about electromagnetic radiation from the meter, the next most common concern among homeowners that opt out of having an advanced meter installed at their residence is the risk of a loss of privacy. This is not an unfounded concern – disaggregation does provide a great deal of personal information about the behaviors of the residents.

While this information can both benefit the utility and the individual homeowner, it is critical that the utility and their comarketing partners protect this personal information with all the safeguards associated with other sensitive personal information, as well as respect requests to opt out of being involved in disaggregation.

Applying Disaggregation Technology to Increase Energy Efficiency Uptake

To explore how advanced marketplace programs can increase the uptake of technologies and upgrades to improve energy efficiency, it can be useful to consider hypothetical examples. For instance, three families living next door to each other in three identical, new tract homes will have very different usage patterns. This is the case even if the appliances are the same and monthly power usage is nearly identical. In this hypothetical scenario, one family may be environmentally conscious and charge their EV with a type 1 charger. The next may prefer cooking most meals at home and keep their home and clothes very clean, while the third may be heavy users of home entertainment and like their space to be cool in the summer and warm in the winter.

The disaggregation application has the potential to discern the usage patterns within each of these homes. As discussed, it is important for the utility to identify the EV owner. They may be eligible for special pricing on their power, could be offered discounts on enhanced charging equipment that would include some power storage, and could participate in demand response (DR) programs to lower their cost and enable the utility to acquire lower cost and/or more renewable power. Similarly, it would be a waste of resources to educate these customers that are already engaging in energy efficient behavior on the techniques they are already using.

The second home may appreciate tips and suggestions on money- and energy-saving options, while the third hypothetical family may be largely indifferent and are willing to continue to pay more than their neighbors to enable their lifestyle choices. Resources dedicated to changing the behavior of the third group may not create any returns for the utility, even if the cost of these efforts is negligible.

Advanced Marketplace Technologies

Utility marketplaces can help address individual needs to lower costs and reduce environmental impact. They do this by taking the information from the disaggregation application, evaluating usage patterns, the energy requirements of the appliance, equipment, or load, and proposing solutions. These solutions may or may not come with the description on how a particular acquisition will save the consumer money or reduce their carbon footprint. The focus is to give the ratepayer a convenient way to address his or her needs with an experience that is similar to any other e-commerce purchase.

In some cases, fulfillment will be achieved in the traditional way of shipping the products to the homeowner's address. For solutions that involve professional installation, the marketplace will offer estimated pricing associated with its trade allies. This can be tricky because many customers resent being quoted a price only to see the costs increase when the contractor is on site. Historical usage information that served as the input to the disaggregation application can be used to minimize this experience.

A key benefit of an advanced marketplace application today is that it can include any applicable rebates that are effective when presenting the pricing. This allows the homeowner to compare available options more easily. It is not unusual for a higher priced, but more effective, alternative to have a lower net price because of rebates. This is often seen with smart thermostats, whose effectiveness in meeting utility objectives allows the utility to provide deeper discounts than would be available for conventional programmable thermostats.

Priorities of Marketplace Applications

It is well understood that the top priority of an e-commerce site is to be profitable for the organization that operates the site. While that can be the priority of a utility marketplace, it is possible, and even desirable, to refine the priorities for a utility marketplace to meet other goals. Examples include:

- **Increasing energy efficiency:** the marketplace could prioritize its offerings to offer solutions that address the least efficient energy users;
- **Reducing carbon emissions:** The renewable power is sometimes curtailed and during certain times of the day, only energy created by fossil fuels is available. It is possible to focus on reducing energy usage among the ratepayers that tend to use more power during the times that fossil fuels are predominantly used.
- **Better serving disadvantaged customer segments:** As seen in Figure 1, there are a significant number of people experiencing energy insecurity. The marketplace could prioritize offerings to people who do so and make it easier and more convenient for them to take advantage of available financing programs and grants.

Fortunately, these priorities are closely related. In an ideal world, all priorities could be met simultaneously with the same level of impact. Practically speaking, given that there are limited resources for targeting different customer segments, the marketplace must have priorities.

Future Enhancements

The current practice is that the marketplace application will present a customer with the net price of a product. This is simple to understand and easy for homeowners to accept. Future capabilities to utility advanced marketplace applications can include the following:

- **Perform a cost-benefit analysis:** Use the homeowners' actual usage patterns to calculate the return of selecting a proposed offering;
- **Actively promote programs to those with the greatest need:** Using the data from the remote audits, the utility will prioritize the homes that have the most to gain from improvements and promote EE solutions and the applicable LMI programs more assertively;
- **Provide information on financing programs:** Programs like R-PACE are specifically structured to remove the challenges of investing in energy saving technologies that have a high up-front cost;
- **Automate the application process to assistance programs:** Integrating the application process and the corresponding pricing can increase the impact of the available programs and offer greater accessibility to support programs.

Conclusions and Implications

Traditional approaches to supporting LMI customers and encouraging all customers to increase their energy efficiency have a proud tradition. The adoption of newer technology, such

as advanced meter infrastructure, disaggregation, remote energy audits, and advanced utility marketplaces offer the potential to target customers more narrowly with solutions that are consistent with their needs and their ability to finance these needs. The result will be an increase in energy efficiency, decrease in carbon emissions, and decrease in energy insecurity, particularly among ratepayers living in or near poverty.

Achieving these objectives involves several changes. First, the state agencies that administer the LIHEAP and WAP programs would need to coordinate with the regulatory bodies and local utilities to explore the feasibility of leveraging the disaggregation applications. While there is advanced meter infrastructure in most residences in the United States (Utility Dive 2021), it is not yet universal. Where it is installed, the utility may or may not have implemented the disaggregation application or a utility marketplace. Utilities can take the initiative independently to help identify suitable candidates for the existing programs. They have an interest in reducing energy insecurity of the ratepayers. The information provided by disaggregation applications can help reduce the needed resources to manage the challenges of LMI customers within their service area. The organizations that make disaggregation applications and provide useful information for an advanced utility marketplace need to collaborate to achieve the interests of the utility, whether that is profit maximization, energy efficiency increases, or carbon emissions reduction.

To simplify the process, marketplace applications can offer the tools to directly collect information from the homeowner and use it to fill out and apply to participate in one of the funding programs automatically. By embedding pricing options in an advanced utility marketplace, the process can be simplified and opened to a broader audience. The simplified application process and the less intrusive audit can increase the participation rate.

Better serving LMI customers requires the support and involvement of all the stakeholders, which can be challenging. There is reason for optimism about using disaggregation to better support LMI customers because all the stakeholders have a common interest.

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