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ENERGY POVERTY RESEARCH LANDSCAPE ANALYSIS

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Contents

1. Abstract

The burden of energy costs on low-and moderate-income (LMI) energy consumers is pervasive. Energy poverty impacts quality of life and introduces economic and health risks for LMI populations. This work is intended to explore the mutual value proposition to both the power sector and LMI populations, of deepening understanding and demonstration around better integrating LMI consumers into the mainstay of the utility business model.

This paper presents findings from a year-long energy poverty research landscape analysis effort. The team conducted the landscape analysis by identifying and systematically reviewing findings from roughly 700 LMI-related research publications, released between 2002-2016. The study ultimately leads to takeaways and implications from four key areas:

1. The customer engagement model can be reimagined and tailored to LMI consumers, to improve program participation and opportunities to realize greater benefits from LMI behavioral change efforts.
2. Utility rates and approaches to mainstay services should be reformulated to reflect opportunities to improve quality of life benefits to LMI consumers, including greater integration and validation of non-energy benefits and time-of-use retail pricing.
3. Opportunities to develop profitable downstream advanced metering infrastructure services such as demand response should be further demonstrated and validated.
4. Demographic and contextual factors that impact LMI consumer behavior, program participation, and response to intervention are dramatically understudied, in particular regarding interplay with housing type, household composition, and health considerations.

The authors intend to provide an up-to-date understanding of the state of play across LMI-oriented energy research, especially critical research gaps, recent convergences and divergences, and leading insights around near- and mid-term implications.

2. Introduction and Objective

Energy poverty is a widespread and understudied issue that affects millions of people around the country. The Texas Energy Poverty Research Institute (TEPRI) works to improve the quality of life in low-income communities by inspiring lasting energy solutions. "Energy poverty" describes a condition faced by many Americans in which the personal cost of consumption needed to maintain a healthy lifestyle creates a significant or unnecessary economic burden. Across the United States, low income communities are highly vulnerable to changes in energy prices; for every 10% increase in home energy costs, 840,000 Americans will be pushed below the poverty line [1]. The Institute developed this whitepaper to highlight the prominent research topics (and gaps) relevant to understanding and, over time, to ameliorating energy burdens among America's low-income residents.

The decommissioning of public funding and inequities in distribution of the benefits from emerging technologies in recent years have exacerbated low-income energy burdens. The Institute hopes to advance the collective knowledge about low-income households and their relationship to energy.

This paper aims to increase understanding of energy poverty and to raise awareness about the state of play in the power sector by providing an analysis of the landscape of publicly available current research. The authors have attempted to present an objective framework of current discussion, while maintaining the integrity of many independent perspectives. This report sets the stage for the forthcoming TEPRI Energy Poverty Research Clearinghouse, which will be a comprehensive and consolidated repository of information and research on energy poverty to be used as a resource for utilities, policymakers, service providers, and research organizations to reduce the time spent identifying and understanding related issues, and to:

- Develop a foundation for state and national level discussion
- Influence program design and share best practices
- Inform policy
- Guide outreach and education
- Develop future research

3. Approach and Methodology

Research on low-and moderate-income (LMI) consumers[c] in the U.S. power sector is scattered. We conducted a rigorous, systematic review of LMI-related research topics released between 2002-2016[d]. We implemented a tailored methodology[e] in three stages:

Stage One: Piloting. We identified dozens of organizations[f] that publish relevant LMI research, solicited input from more than a dozen electricity market research and program administration experts; downloaded organization reports; and analyzed roughly 100 reports to content characteristics and inform our search criteria and analysis approach.

Stage Two: Content Search. We developed a manual algorithm to implement source collection from 184 unique search terms, reviewed the first 50 results from each search term; and developed a final document database of more than 600 reports for analysis.

Stage Three: Analysis. We developed a taxonomy of topic definitions from the ground up[g] and applied the taxonomy categories to topic-containing excerpts from sources. We then analyzed the salient aspects within each topic area.

Sources in the database were limited to reports that met the following criteria:

- Focus on LMI consumers, and the power sector;
- Represent or reference a downloadable report, white paper, or study;
- Discuss a single study, multiple studies, or meta-analysis of studies;
- Discuss research conducted in the U.S., using data developed in the U.S., or representing U.S. consumers or other market actors;

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[c] We use the term low and moderate income (LMI) consumers to describe the population most widely afflicted by energy poverty. We also prefer this term because across the hundreds of studies and reports we consulted, the range of what is considered "low-income" varies, as do prevailing wage considerations, making LMI a more accurate characterization.

[d] The fifteen-year timeframe is a simple constraint to focus our efforts to a period of recent research activities. Any other meaningful attributions to this timeframe are coincidental.

[e] See Appendix 7.1 for further discussion of the research methodology.

[f] See Appendix 7.2 for a complete list of relevant organizations. Organizations qualified by meeting the following conditions:

- Published more than one study or report focused on energy poverty between 2002-2016, and
- The work was generated, enhanced, or provided greater visibility as a result of the organization.

[g] Our ground up approach separates any relation to the search terms used to generate the reviewable sources.

- Be publicly available for no charge (i.e., not behind a paywall); and
- Be published between 2002 and 2016.

The following sections discuss the topic analysis results. Section 4 discusses the high-level and granular topics, as well as the outcomes and literature perspectives that emerged. Section 5 offers takeaways, implications, and recommendations.

4. LMI and Energy Research Topic Landscape

LMI and energy-related research published between 2002-2016 spans dozens of topic areas, and many cover multiple topics and implications that extend beyond the primary focus. Each section of this paper is framed to convey meaningful information about the topic analyzed, which taken alone may not convey the full intent of a given report. We follow this approach for two reasons. First, researchers and organizations often cover the same topic in somewhat different terms, reflecting the author perspective. For instance, a program evaluation may discuss the implications of program outcomes for LMI consumers differently than an organization that develops a study to motivate awareness or market or policy changes. Second, the framing of topics change over time as power sector markets evolve. For instance, in 2014 and 2015, discussions around the implications of dynamic pricing tended to be anchored by findings based on real data, while earlier reports were more conceptual.

This analysis largely focuses on the body of work surrounding the impact of electricity access on LMI customers. The topics in this section reflect our best attempt to establish a coherent framework for published LMI research. Any attempt to do so will fall short of perfection, but the discussion is rich, comprehensive, and it conveys the perspectives of 15 years of research in the parlance of contemporary issues.

4.1. Energy Burdens

The personal financial and health costs of consuming sufficient energy to maintain a healthy lifestyle can substantially impact quality of life for LMI populations. "Energy burden" describes the percentage of total household income spent on energy. The implications vary across the country, and the housing environment in which LMI populations live. Each energy burden differs in acuteness of the hardship to LMI consumers and the difficulty of resolving, based on a combination of variables, including fuel type. Much of this paper focuses on electricity as a retail commodity. Exploration of other fuels including natural gas and heating oil will be the focus of future TEPRI research.

Causes

High energy burdens are driven by several dynamic elements. A major contributing factor of energy burdens is housing type and quality, noting that many low-income residents live in homes with sub-standard insulation, as well as inefficient appliances, windows, and lighting [2].

Because low-income households often rely on unpredictable revenue streams, they are especially vulnerable to fluctuations in energy bills [3]. Owner-occupied housing tends to consume less energy per square foot than rentals, implying a lag in energy efficiency upgrades to rental buildings [4]. Split incentives, limited financial resources and lack of sophistication are causes for lack of energy efficiency improvements in rental properties [4]. Studies point to the particularly poor energy performance of manufactured homes [5,6]. In multi-family housing, both the tendency to adopt a least initial-cost construction strategy [7], and design of subsidy programs [8] leads to lack of energy-efficient designs. The top behavioral factor contributing to energy cost in warm climates is the cooling set point in the summer [9].

Effects

In addition to energy effects, high energy burdens are linked to significant negative non-energy effects, many of which have exacerbated effects on families with children [10]. The adverse effects of energy burdens on the mental [11] and physical health [12,13] of the low-income population are frequently observed. Incidences of increased illness [14] and morbidity [15], derived from asthma [13], depression, anxiety [11], diabetes [3], stroke, and heart attack [11] have all been attributed to low-income energy burdens.

The effect of energy burden on the housing stock of low-income populations is noticeable. Deteriorating housing quality caused by low air quality [16], water leaks, and accumulation of mold [17] can be directly tied to poor energy performance. These effects contribute to the high housing instability observed within energy-poor communities [17], with higher rates of eviction [3], moving [12] and homelessness observed [3]. For many, housing is the only asset of value held [18], and depreciation of this asset can lead to increased financial stress.

Combinations of low income, high energy demands, and poor housing quality can force difficult tradeoffs between essential needs [14,15]. Air conditioning, heating, and lighting are considered essential and critical for the survival of elderly and infirm citizens [14], but spending on energy costs can directly take away from other family requirements [2]. Utility bills often force residents to forego necessary food purchases [19,20], in addition to medical care, clothing, and transportation [20].

Low-income communities suffer a disproportionate impact of air pollution and health hazards [21] and, in general, low-income households are likely to suffer harsh impacts from climate change [22].

Senior Citizens

Low-income senior citizens tend to live in distressed housing, and they are particularly dependent on energy stability as heating, cooling, and lighting are critical for their survival [23]

[24]. Due to fixed incomes, seniors are disproportionately impacted by high prices [23] and need to carefully budget use of electricity, preferring more stable bills [25]. Still, technology innovations may allow seniors to stay in their homes with electronic monitoring of health [19]. Major nonprofits and public funding programs support maintaining and improving homes of seniors [26]. LIHEAP specifically prioritizes outreach to vulnerable elderly [27], but many low-income seniors do not participate in programs for which they are eligible. Reasons include a lack of familiarity with programs or discouragement with complexity of enrollment process [28], as well as long investment payback timelines for energy efficiency upgrades [23].

Barriers to Resolving Energy Burdens

Financial barriers present the most significant obstacle to resolving energy burdens [29]. Federal and state funding for assistance is limited and volatile. A lack of access to capital or insufficient credit can prevent LMI customers from taking advantage of programs that target clean energy or efficiency upgrades, due to high upfront costs [2,30,31]. These programs also languish in attracting LMI customers due to the lack of financing options targeted at this customer base [32,33].

Often, low income families do not have access to quality housing, are renters, have old or inadequate appliances, lack sufficient energy education, and have limited free time to manage their consumption, all of which present barriers to energy savings [34]. The housing types of low-income communities are observed to provide significant obstacles to reducing energy costs, with multifamily, mobile, and manufactured housing identified as particularly problematic [35,36]. Multifamily buildings often raise split incentive issues [29] between landlords who pay for improvements and retrofits, and tenants who pay energy bills [37]. Split incentives are identified as a primary barrier to multifamily low-income energy efficiency programs [38]. Manufactured and mobile housing suffer from outdated efficiency standards and emphasis on inexpensive design [5]. Safety and building integrity concerns also act as barriers to retrofits, since many programs will not touch unsafe housing until repairs are completed [39,40].

Low income populations are difficult to reach through traditional utility communication channels, which often limits program participation [41]. Language barriers and lack of internet access further exacerbate this problem [30]. Other social constraints of poverty, such as limited available time [42], low social trust [43], and irregular schedules [44] also present barriers to program access. Furthermore, many of the government programs intended to alleviate energy and housing burdens are fragmented [45], and they present overwhelming obstacles to low income enrollment [46].

Existing Solutions and Benefits

The population-wide benefits to ameliorating energy burdens are widespread, ranging from economic, to improved health, job creation, and environmental improvements. Clean energy [47], energy efficiency [14], weatherization [48], financial assistance [12], demand response, and specialized rates [49] have each demonstrated benefits to LMI consumers. Bill reductions, through whatever mechanism, provide the most benefit to LMI consumers [50]., by muting the economic hardship exacerbated by energy burdens [15], and reducing the incidence of tradeoff scenarios such as the 'heat or eat' dilemma in which consumers are forced to choose between paying for utilities or putting food on the table [48]. The financial benefits of some interventions impact landlords and tenants, helping LMI residents while reducing building maintenance [51], increasing asset value [45], and improving occupancy rates [52].

LMI outreach, when done effectively, can reduce the cost of service and improve bill impacts [53]. Building trust and engagement by tailoring outreach to the specific demographic, socio-economic, housing, and geographic characteristics of LMI populations, are essential to fostering trust and engaging these audiences [54]. In many cases, focusing more on LMI improves quality of life, while avoiding utility- and ratepayer-costs [24,53]. For instance, in some markets, utilities have seen up to 40% reductions in arrearages, with LMI consumers saving as a result of weatherization [55].

Service provision itself should also be tailored to LMI consumers [54,56]. This population tends to be well served by whole-home energy efficiency programs, such as sealing the home envelope, adding insulation, and repairing ducting [5,54], as well as education on thermostats and plug loads [9,57]. When designing programs, utilities and program administrators should assess the appropriateness of technology-based programs for LMI consumer feasibility [58], which, in some instances, do more harm than good. Creating living-wage jobs yields widespread -benefits [32]. One study demonstrated that energy efficiency programs create nine to 11.6 jobs per $1 million invested, a rate higher than the economy-wide average [59]. Other community-wide benefits realized through the energy savings programs include the reduction in future utility generation capacity investment [60], as well as lower disconnection rates, and improved grid resiliency [61], the costs of which are borne by ratepayers.

Programs that benefit LMI consumers may also lead to environmental benefits, including helping to meet emissions targets [61]. Environmental hazards often disproportionately affect LMI consumers [32]. The extent to which environmental remedies dovetail with air and water quality can produce immense health co-benefits [45].

The potential health benefits of relieving energy poverty are vast and noticeable. Two health impacts that frequently appear in the research include asthma and respiratory incidence [62] and malnutrition which result from the 'heat or eat' conundrum [63]. These health impacts are especially stark in vulnerable communities, primarily children and people of color [62]

4.2. Behavior

Household behaviors contribute to overall energy consumption and, as a result, impact energy costs. Effective methods of affecting consumer behavior for desired outcomes can be elusive; however, the estimated U.S. energy savings potential associated with LMI behavior change is $13 billion [62]. Understanding key factors to successful behavior modification is critical to achieving savings goals.

LMI Consumer Behavior

Consumption Patterns and Profiles

Energy use among LMI consumers is correlated across race, income, and geography [53,64]. LMI household consumption is less elastic than non-LMI consumers, and can frequently be attributed to poorer families living in large but older, inefficient homes. LMI families often lack the ability to respond to price signals, due to unique occupancy circumstances and technology barriers, and that they already tend to be customers with flat load profiles [25,65–67].

LMI consumers' inelastic load profile sometimes leads to dynamic effects in response to market changes that differ from non-LMI responses. LMI consumption tends to increase if electricity costs are included in rent [4] and weatherization measures can result in a "rebound effect" or increase in consumption [68]. Both effects are due to a condition in which LMI consumers use less energy than their true demand, which may lead to negative effects on comfort, health, and quality of life.

Consumption Factors

LMI households' response to energy costs is often constrained by their housing context. Studies point to both contextual and personal factors that constrain LMI energy consumption behavior; including:

- Total household and discretionary income;
- Whether a consumer rents or owns a home;
- Housing type and energy efficiency of the home;
- Patterns of household activities and occupancy; and
- Medical needs that affect heating and cooling, or that require extra power supply precautions.

All these factors affect how LMI consumers respond to prices and intervention. Consumption behavior in hot and humid climates are most significantly driven by cooling set-points, [established] energy-saving practices or habits, and indoor air quality. Household composition also tends to be pertinent [69–71]. The type of housing is an additional factor. For example, LMI manufactured homes residents have been shown to consume an average of 53% more energy per square foot than consumers in other forms of housing [6].

Response to intervention

LMI consumers tend to be both low information consumers and difficult to engage for energy savings efforts. Each of these characteristics steepens the task of reducing LMI energy burdens. Further confounding the issue, improving energy awareness does not necessarily increase the ability to change behavior [72,73]. LMI consumers respond better to people-centered interventions, and behavioral strategies may be more efficient for LMI consumers than are efficiency upgrades [74]. Examples of strategies that have effectively impacted LMI energy consumption include nighttime thermostat setting, installing smart power strips, quantifying monetary losses associated with high-use electric appliances, and technology-swapping programs.

Energy Savings

LMI consumers respond to energy savings interventions differently than non-LMI consumers, but tailored interventions can be effective. Demand management through weatherization and efficiency programs are prominent opportunities [75,76]. Weatherization is the most common LMI energy efficiency intervention [77]; however, expanding programs to include appliance [55], lighting [78] and clean energy [79] upgrades offer greater savings potential. Refrigerator [68] and air-conditioning upgrades [80] are a source of potential electricity savings. Savings potential is greater in regions with extreme climates [37]. Significant savings have been established in behavior change [58] and dynamic pricing [81] programs.

Programs that target multifamily and manufactured buildings have great potential for achieving deep and persistent energy savings if the split incentive barrier to retrofits can be overcome [36]. Both impact typically aging and inefficient housing stock [37]. Multifamily buildings offer good return on program investment due to low transactional cost and economies of scale [38], with electricity and natural gas retrofits commonly identified as sources for energy savings [59]. One study estimated that as much as $16 billion in energy cost savings could be realized from multifamily buildings [83].

Rebound

The rebound effect was well covered by the literature, and several studies noted that while the effect does exist, because the direct and indirect effects are generally less than 100% the measures are often still worthwhile [84–86]. The rebound effect tends to be higher for low income households than for wealthier households [87]. Often for low-income groups, the rebound is associated with an increase in comfort and well-being [86,88], overall safety [89] and demand for new energy services [88], though more study is required to fully understand these non-energy benefits [90]. When discussing rebound effects, other related effects should be considered such as substitution effect, income effect, and economy-wide rebound effects [90]. Still, rebounds tend to diminish when viewed at the economy-wide level [88]. Because the magnitude of the rebound effect varies by wealth, income, and energy use level, the characteristics of the target group should be incorporated in efficiency policy measures and estimates of predicted savings [91].

Strategies

Equity concerns are integral to low-income strategies. As a whole, the industry looks for methods to reduce the impact of energy sector disruptions [92] on low-income customers by compensating mitigation strategies [93]. Reducing cross-subsidization of renewable generation [32] and improving the distributional efficiency of rebates [10] are two prominent equity themes.

Streamlining LMI energy program design and improving coordination of existing resources are proven strategies that drive program success [39]. Removing barriers to program access and engaging and connecting stakeholders at all levels are identified as vital to the design of scalable programs [30]. Examples include incorporating energy retrofits with non-energy upgrades [94] and purpose-driven partnerships between states and utilities [31,95]. Utilities, banks and investors, tenant and ratepayer advocates, building owners, affordable housing developers, and public utility commissions (PUCs) are all integral to developing and supporting these effective LMI programs [29].

Aggressive and targeted marketing and outreach efforts for programs to access hard-to-reach LMI customers is critical [43]. Nuanced marketing strategies are vital for behavior change programs [53] that leverage existing customer relationships, such as community-based organizations [96]. Energy education alone can be an effective, low-cost strategy [73,74].

Better access to data, surveys, and a greater focus on LMI customer monitoring engenders more effective customer targeting [55]. Surveys, audits [78], advanced metering [97], census data [55], and GIS [98] have each been pinpointed as useful information sources. This information can pay ongoing benefits to future program designs [78].

Behavior Change

Stimulating behavior change can be a powerful strategy for reducing energy burdens [99]. Behavior interventions are relatively inexpensive methods of achieving energy savings, making them particularly palatable in LMI program design [100], and can easily be incorporated into complementary program design such as EE programs [100,101]. Often technology retrofit programs require behavior modification strategies to avoid rebound effects [55] and realize energy savings [73]. Achieving sustained population wide behavior modification that leads to continuous energy savings is challenging. While LMI customers have demonstrated a willingness to make behavioral changes, contradictory evidence suggests these programs struggle to translate to long-run changes in behavior [58].

Behavioral factors that have been identified as targets to achieving energy bill savings for LMI customers include, heating and cooling thermostat set points, energy saving practices, lighting and appliance behaviors and indoor environment quality [9]. Environmental and climate attitudes among LMI communities mirror the general population, however targeting these attitudes for behavior change is an ineffective strategy for reaching the LMI population [44,102].

Direct interaction with LMI clients via people-centered strategies has been identified as the single most effective behavior modification strategy [55,58,74]. Interactions should focus on energy education that can be tailored to diverse LMI customer circumstances [73]. Education strategies should require periodic follow-up to ensure persistence of behavior change [58]. Access to increasingly granular bill information is often cited as potential strategy for behavior change [44], as are programs that use technology to disaggregate client energy use to identify energy saving opportunities [58]. However, there is currently limited evidence to suggest either of these strategies actually motivate behavior change [72].

It is very challenging to measure the energy savings that result from behavior change, which makes evaluating programs very difficult [44]. Furthermore, utilities understandably prefer to invest in programs with demonstrable results, which can complicate attracting funding for these programs [100]. Designing and defining measurable criteria for evaluating behavior change programs is integral to benchmarking and improving the value of behavior change programs [58]. Pre- and post-program audits, surveys and interviews, have been identified as possible strategies for evaluating these criteria [89,103].

Program Design and Optimization

LMI energy conservation program design and optimization primarily emphasize identifying key criteria for successful programs. The criteria for realizing energy savings can take several forms, including inefficient appliances [55], high pre-program consumption [104], and quality of housing [102]. However, the most common criterion identified is understanding the characteristics of program customer bases [44,105]. Customers that pre-enrolled [106], do not receive federal Low Income Housing Energy Assistance Program (LIHEAP) funds [44] and carry below-average arrearages [44] are identified as key drivers of success. Recognizing these key criteria allows policy makers to design programs that will optimize energy conservation.

For example, in populations prone to rebound effects, policy decisions and program design are greatly improved by targeting and accounting for rebound effect as a key criterion [55,85]. Improving outreach to low-income customer classes through targeted marketing and behavior education [106], coupled with feedback from metering data [44] have also been shown to yield energy savings. Finally, incorporating complementary program funding is an efficient way to broaden program reach [107].

Information and Education

The use of information, in the form of more informative bills and increasingly frequent consumption feedback from periodic to continuous/real-time, to drive behavior change and energy conservation is widely debated. Advocates for using the increased information and data, made possible due to the roll-out of advanced metering infrastructure, contend that providing customers increased access to consumption information can increase their awareness of energy use patterns and will induce conservation behavior change [72]. Countervailing studies show increasingly frequent access to data through continuous monitoring does little to induce actual behavior change and produces no significant energy savings [72]. It is worth noting that nearly many low-income customers lack internet access, and care must be taken to ensure critical information is still accessible by these customers [38]. Another strategy that utilizes increased access to energy consumption information includes giving low-income customers access to shadow bill information, whereby customers can contrast their current bill with how they would perform under alternative tariffs such as dynamic pricing [108]. This would be of interest to low-income customers who have limited ability to shift load in response to these rates.

Landlord Engagement

Achieving landlord engagement could significantly increase the efficacy of low-income energy-saving programs. Multifamily building owners and housing authorities have formed tight networks and partnerships nationwide [109]. Consequently, achieving access to these organizations will leverage both the established communication structures, centralized decision making, and broadened low-income customer base, thus potentially enhancing the penetration of these programs [78,109].

Tenant Engagement

Tenant engagement is a central strategy to the success of behavior change programs [99,100]. Tenant engagement programs offer a low-cost, low-risk strategy to achieving energy savings, and these programs can be designed to complement strategies such as energy efficiency retrofits [100].

Separately, programs such as virtual net metering, which share the benefits of community solar, also address tenant engagement [110]. These programs, which are designed to redirect the benefits of multifamily building solar installation towards tenants in addition to the owners, are also effective forms of tenant engagement [110].

Contractor Engagement and Compliance

Contractor engagement and compliance are important aspects of effective LMI program management. Established communication networks such as with existing program and subsidized housing contractors, as well as community based organizations and landlord-tenant relationships, offer experienced outreach infrastructure and expertise that can be leveraged for improved program penetration and marketing [34,38,111]. Clear metrics within program design that target the most efficient pathway to large energy savings [56] must be a key focus. Metrics such as the ability to invest in retrofits, high per-unit energy cost, retrofit costs, cash flow analysis, and other financial measurements should be coupled with clear work specifications and instructions, as well as contractor management and supervision [20,56]. One study recommends the publishing of a comprehensive how-to guide to disseminate these strategies to incoming program developers [100].

4.3. Programs

Programs are the primary mechanism by which utilities and state and local governments implement efforts to affect energy efficiency and bill assistance. Thoughtful and well-informed design is critical to ensure programs meet their performance targets, including penetration and cost-effectiveness.

Energy Services

Utilities need to balance certain metrics to support LMI consumers and demonstrate results (or meet mandates), while limiting the financial impact on ratepayers [13,105]. Taking care of LMI consumers is crucial to prevent negative health and economic effects [21]. In many states LMI consumers are afforded relief by statute, and often even protected from disconnection due to non-payment [112]. Specialized energy services, whether or not prescribed by policy, can benefit LMI consumers by muting the impact of price volatility [112].

State and federal policy around LMI energy services has been active for many years. Calls for more nimble administration of LMI services have grown, while demonstration of more sophisticated behavioral techniques could increase the amount funds spent on energy efficiency from marketing budgets [100]. Greater coordination between utility programs, and across utility territories, could lead to more effective customer programs [40,113]. PUCs may be able to stimulate greater utility investment in LMI weatherization for demand side management, by permitting calculation of both energy and non-energy benefits [95]. Non-energy benefits (NEBs) such as declines in rates of respiratory illness, if permitted to be accounted for in utility programs, could diversify and improve program offerings for LMI consumers [114–117]. NEBs provide direct program benefits, consumer insights, and improve the effectiveness of marketing and targeting efforts [115]. For some programs, ratepayers must benefit from program expenditures, which can be enriched by including NEBs [116].

Demand Response Programs

Demand response has a mixed performance record with LMI consumers. In some cases, studies have shown that LMI consumers are less suitable participants and see less savings [118]. For example, in one study, LMI consumers saved 10% during a critical peak pricing pilot, while non-LMI consumers saved 17% [118]. Several factors have been identified around why some pilots have shown subpar performance. Because LMI consumers are more cost conscious they may use high load appliance like AC more sparingly in the first place, and due to household size and older housing stock with limited retrofits, they are generally presumed to have less elasticity in their load [118].

In some cases, however, LMI consumers are saving significant amounts, and some argue that they are in a position to better appreciate the savings, due to the marginal benefit of bill savings among lower income consumers [119]. It's not clear the evidence that LMI consumers save less through demand response programs is accurate [25,119]. Most evaluations that demonstrate this have statistically insignificant samples of LMI consumers, and were not tailored for LMI residents [25].

Financing Mechanisms

A potential avenue for funding energy efficiency retrofit programs for homeowners is through on-bill financing (OBF), whereby utilities pay the up-front costs of installation overcoming a major barrier to retrofits [106]. These costs are then paid back in installments on the customer’s bill and partially offset by savings from efficiency improvements. OBF, however, can ignore the inability of LMI customers to handle bill increases and lacks the loan and credit protections of regulated lenders [120]. Other suggested options for financing low-income programs include customer-wide system benefits charges [121] and performance-based contracting [56] where retrofit performance is tied to service contracts. Program designers should utilize program sponsors, government agencies, and funding that can be leveraged to partner with lenders that work with low income programs [122,123].

Another focus is the importance of quality data, information, or financial tracking throughout program lifecycles [50]. This data informs and motivates program stakeholders and financers, by allowing them to benchmark and monitor the performance of their investments [50], monitoring also allows program sponsors to effectively screen for projects that fit certain financing models [37]. For example, monitoring of multifamily building retrofits has provided a high-performing financing opportunity due to economies of scale, contrasting the prevailing notion that split incentives would be a barrier to program success in this sector [94].

Community Development Financial Institutions (CDFIs) play an important role in financing and can provide expertise and experience in working with borrowers at the local level [60][94]. A major aim is to overcome poverty and disadvantage by investing the infrastructure [124].

Community Based Organizations

State and local governments partnering with community based organizations to leverage existing expertise and good relationships within the community is vital to program success [40,125,126]. Local networks can include churches, universities, and local businesses [127], as well as food banks and community action agencies that administer federal weatherization funding [40]. The collaborative network structure can create innovative community based marketing and outreach models [11,34], and allow funds to be allocated at the local level where community-specific needs are best understood [26]. Key factors to program design with community based organizations include developing strong local relationships [56,99], thinking carefully about overarching goals, and simplifying and streamlining processes [128]. Many organizations are working to develop "turnkey" approaches so that including access to financing, assessment, incentive, and assistance are all available through the same channel as a one-stop shop for access to low-income energy services [104,128]. Additionally, these networks can serve the convening function of coordinating policy, regulatory, and program implementation [60]. Funding comes from major non-profits and public funding programs [26], as well as CDFIs.

Program Design

Program Design Principals

Key methodologies for design optimization include utilization of benchmarking tools, focus on quality assurance, use of blended incentives and direct install approaches, and local governments and utilities incorporating demographic information into program design and distribution channels [31,37]. Tools to reduce energy burdens include discounts, efficiency investments, pricing schemes, and debt management [27]. Potential exists for sustainable returns through non-energy benefits related to health, economic, and social outcomes [62].

Measurement Challenges

The research shows that investment in evaluation is required to ensure effective program design at scale, but evaluation can be challenging [56,122]. Protocols must be tailored to building types, types of retrofits, and occupancy situations [56], and consider macro effects like market conditions, economy, weather, and customer attitudes [89]. The most reliable information combines different evaluation approaches [1], and methodologies developed to statistically handle bias, measurement error, low response rates, and rebound effects [85,129].

Measurement Opportunities

There is an opportunity for development of sector-wide standards for evaluation and measurement to strengthen program design, including leveraging the federal housing portfolio [130], coordinated data gathering and evaluation efforts [56], automating data access platforms, and financing standards [50]. Including non-energy impacts in financial modeling also has the potential to reframe program outcomes [114,117,131].

Innovative Program Design

Comprehensive program designs include energy efficiency measures to reduce consumption, coupled with bill credits based on distributed generation assets [110]. Low income weatherization customers also benefit from automatic enrollment of other income-based services [2], and energy service organizations have developed methodologies to incorporate these suggestions [56]. Several models for funding and financing mechanisms include development of creative access to project capital that includes recognition of value through energy savings, as well as subsidy deferment [130], suggestions for seeding a robust capital market system through federal policy [130], using energy savings insurance to mitigate perceived risk of borrowing on energy savings [104], effectiveness of green banks as successful models to promote green energy investment [132], and pay for success models to scale initiatives [122].

As previously identified, program design should incorporate non-energy benefits to include arrearage reduction, community economic development, and better service to customers by both property managers and utilities [56,110,116].

4.4. Rates

Rates available to LMI consumers through their electricity provider will have a direct effect on the total household cost of electricity and therefore energy burden of LMI consumers. Various rate structures may have different implications for LMI than on the general population due to unique load profiles.

Time of Use and Dynamic Pricing

The impact of dynamic rates on low-income customers requires resolution of whether the comparatively low and flat but inflexible load profile will allow them to reap the savings attributed to dynamic rates. Advocates for dynamic rate setting argue that the relatively low consumption and flat load profile will translate into bill savings for LMI customers even in the absence of load shift [81,119,133]. Furthermore, some studies provide evidence that traditional assumptions about low-income customers' inability to load-shift in response to price signals were false [81,134]. Conversely, many studies assert that the inflexible load profile of low-income customers, especially highly vulnerable populations (seniors/people with disabilities etc.), will expose them to critical peak period prices that will result in bill increases [135,136]. These concerns are also reflected in the number of studies that call for further research to provide further quantification of the distributional efficacy of dynamic pricing [25,119,135,137].

Another point of emphasis is the willingness of low-income customers to enroll in alternative rate programs if they are properly targeted and perceive they will realize bill savings [138]. This aligns with observations that low-income customers do not show significant net-effects from default enrollment compared to other customer classes [139]. Concerns exist about the complexity of dynamic rates and whether certain residential customer classes, most notably low-income groups, will be able to understand and respond to them [140]. These concerns are bolstered by the emphasis on the importance of well-designed outreach and education programs coupled with rollout of new rates [141].

Critical Peak Pricing and Inclining Block Rates

As with time of use and dynamic pricing, there is limited consensus on whether the low, steady but inflexible load profile of low-income customers is likely to reap bill savings under critical peak pricing. One pilot study showed that critical peak pricing bill variation for low-income groups were statistically insignificant or caused increases between 5-10% [93]. Several others concurred that the limited ability of low-income customer to shift demand in response to critical peak pricing warranted consideration when designing the rate [135].

Conflicting studies maintain, however, that low-income customers have demonstrated the ability to respond to critical peak pricing [119], and that low-income customers will benefit both from both the lower rates and shielding from increased fixed cost recovery due to peak load attenuation under critical peak pricing [142,143]. Further studies also support the equity of critical peak pricing by demonstrating statistically indistinguishable bill changes between low- and high-income groups, arguing that peak pricing does not unfairly punish low-income groups [93]. Another key finding is that strong interest exists amongst low-income consumers in enrolling in or participating in critical peak pricing programs [138,139].

Inclining block rates tend to achieve income redistribution in the top income bracket; however, these rates can introduce the risk of higher bills for low-income families with large and older homes due to the inability to respond to price signals [69].

Equity

Rate-based energy service programs can improve equity by better tailoring outreach for LMI consumers, making program participation more accessible for financially constrained consumers, or by emphasizing job creation opportunities [21,144,145]. Programs sometimes exclude LMI consumers by requiring financial input, even if there is significant payback, while others are unintentionally misleading [124]. One example is pre-pay programs, which are better suited for slow-paying rather than financially constrained consumers [146]. Program design solutions can likely remedy these deficiencies.

However effective they may be, LMI services make up a significant amount of retail residential program expenditures – between one fifth and one third overall [40]. Public goods programs, however, need more inclusive strategies to improve opportunities for access. The current suite of energy service programs is severely deficient when it comes to engaging LMI communities of color [21,31]. As reforms are developed, many studies argue for including non-energy benefits to broaden the available toolkit of interventions from which programs can draw [115].

Fixed Cost Recovery

Mechanisms like fixed bill and minimum bill charges are sometimes used to tie retail electricity bills more closely to the cost of service. Such mechanisms potentially introduce disproportionate increases for LMI energy bills [147,148]. The case against fixed charges contends that they are an inequitable and inefficient means of cost recovery that shift fixed costs to low-income customers who tend to have low usage profiles and tend to impose smaller fixed costs per customer [149]. LMI consumers are inadvertently penalized for their flat, inelastic load profile, because distribution costs are driven by peak demands, and on-bill fixed charges tend to increase bills for low-usage (low-income) customers [148].

Arguments against fixed customer charges also include the dilution of price signals to conserve and that traditional volumetric rates produce desirable distributional consequences [66,70]. Conflicting studies argue that volumetric charges do not effectively achieve these distributional goals, and more equitable fixed cost recovery can be achieved through marginal cost pricing [70].

Virtual Net Metering

Virtual-net metering (VNM) undergirds the leading community solar model for expanding the distributed solar market to broader consumer segments. VNM increases market access more efficiently and effectively than other community solar offerings such as group billing [97,150]. Several authors point to the driving fundamental advantage that community solar breaks the link between the subscribers and a single geographic area, enabling both remote siting and a diffuse subscriber base [97,150]. VNM also provides a more palatable community solar model for utilities, which can stay involved in the customer relationship and leverage their experience with complex billing programs and energy programs [97,151]. Furthermore, while many studies view VNM as being well positioned as a community solar enabler, several also express the opinion that more effort is needed to resolve regulatory issues and improve implementation of utility allowance rate structures and engagement of key market actors [33].

Cross-subsidization

Cross-subsidization resulting from distributed energy resources has received a lot of attention, and can be a barrier to PV adoption by LMI consumers [32]. A prominent issue around net energy metering is cross-subsidization leading to depleting funds for critical grid infrastructure maintenance and other system costs, which ultimately are borne disproportionately by LMI consumers [152,153]. This same strain of argument identified that the mechanism that depletes funds for grid maintenance also depletes funds for public goods programs. A final argument emphasizes a perverse incentive effect with net energy metering, disproportionately shifting costs to low-usage consumers [149,152].

4.5. Government / Policy

Government and policy mechanisms designed to target energy poverty should focus on streamlining and leveraging funding from existing programs such as LIHEAP, subsidized housing through HUD, climate policy and WAP to create more expansive programs that expand the scope and impact of currently 'siloed' policy goals [39,45,154]. Emphasis is placed on incorporating weatherization and energy efficiency programs and standards into government subsidized housing, where funding and authority is fragmented between HUD and DOE, limiting the reach of programs [19,130]. A strategy for achieving this could involve updating the HUD energy building codes, which have not been revised for manufactured housing, for example, since 1994 [5,155]. Weatherization and energy efficiency programs are highly decentralized and state implemented [56], which, despite broad eligibility criteria [95], currently only reach a small portion of LMI consumers. Weatherization programs have been shown to be cost effective in several studies [55,156].

The Low Income Housing Energy Assistance Program (LIHEAP) is a federal government program that provides bill assistance to income-eligible customers [56]. At the time of publication of this paper, the future of both LIHEAP and WAP is uncertain with proposed federal budget cuts targeting both programs. Limited and volatile [46] LIHEAP funding is only able to assist a small minority of eligible customers [157], catering to about 5.3% of the residential bill for low-income customers [112]. LIHEAP funding prioritizes particularly vulnerable households including the elderly [27] and families with young children [12]. There is some disagreement about whether low-income distribution programs should be the domain of the government or utilities. While some studies argue that utilities have a mandate to pursue such programs [112], and others argue that it is the charge of the government [137], the consensus in the literature is that increased coordination between stakeholders at all levels will broaden program impact [39,45].

Tying LMI energy efficiency programs to broader government climate policy objectives is another key area of interest [158]. Two major strategies for this are linking low-income efficiency programs to government funding to reduce emissions [159] and ensuring any carbon tax or reform redistributes funds towards vulnerable populations [158]. Policy that targets the increased adoption of renewable energy should also target low-income communities [110], including using state renewable portfolio standards to stimulate community solar [97], government backed loans [132] for LMI customers and encouraging funding for renewables on subsidized housing [124].

Clean Power Plan (CPP)

At the time of publication of this paper the future of the CPP is uncertain. We have chosen to include our analysis with the hope that it may better inform future climate change discussion. The overarching themes surrounding the CPP focus on the benefits it will provide to low-income communities through increased investment in energy-efficiency and weatherization programs [24,160], access to renewable technology [24], on-bill reduction [161] and green sector jobs [24]. Also highlighted are the various health benefits recognized by the low-income population due to curtailment of carbon emissions, which inequitably effect vulnerable low-income communities [24,161]. Strategies to meet the Clean Energy Incentive Program (CEIP) allowances set aside for investment in energy efficiency for low-income housing under the CPP are required [126]. Under their current design, it is contended that it is unlikely that the CEIP targets for low-income housing can be met, and that they provide little incentive for investment in the sector [24,126]. An option to redefine the CEIP to target a broader base of low-income customers and expand the allowances to include renewable energy programs will help achieve the aims of the CEIP, while maximizing the number of households impacted [24]. A 2014 study argued that regulating greenhouse gases increases fuel costs, which can affect LMI populations and senior citizens [23].

Regulatory Opportunities

Encouraging results have been observed from both subsidies for energy efficiency that allow for pooling and encourage flexible distribution [122], and in government loan guarantees that encourage private sector investment in low-income renewables [61].

Opportunities exist for strategies to efficiently capture energy poverty issues in existing or future energy regulation, including finding ways to equitably distribute any future carbon tax revenues back to low-income groups through the existing tax system [162] and mandating community solar projects direct a proportion of their capacity to the low-income population [110]. The justification of such intervention invokes the 'general charge' of utility commissions to maintain public health and safety as an obligation to protect low-income customers [112]. These policy interventions have had success in broadening access to renewable [20,110] and weatherization programs [20].

Under a carbon tax, low-income populations will suffer a loss of purchasing power due to higher energy prices [162]. Strategies which offset this distributional impact, and efficiently shift tax revenues back to low-income populations through tax rebates [158] or supplemental payments [162], are integral in designing a carbon tax.

4.6. Technology

Technologies exist that have potential to reduce energy burdens for LMI consumers, but may be unavailable for a variety of reasons, including upfront capital costs and incentives for implementation.

Equipment Upgrades

Split Incentives

Split incentives are a significant financial barrier to the widespread implementation of low-income energy efficiency measures in multifamily housing. Split incentives are ascribed to circumstances in the multifamily market where property owners who do not pay tenant utilities have no incentive to invest in energy efficiency measures from which they will see little to no return on investment, as the savings will be reaped primarily by the tenant [56]. Less common, but also possible, is that when the property owner is responsible for utilities, tenants are less incentivized to undertake energy efficiency investments or actions [37].

Several key strategies exist to overcome the split incentive obstacles to landlord engagement in low-income weatherization and energy efficiency programs. The foundation of these strategies are programs including 'energy efficiency leases' and 'clean energy utility allowances' that aim to better align financial incentives between landlords and renters to invest in these programs [96,163]. Furthermore, existing renewable or solar programs targeted at low-income groups such as community solar, renewable tax credits and virtual net metering could also be modified to minimize barriers to landlord adoption by targeting multifamily and rental housing [96,110].

Integral to overcoming split incentives and achieving landlord engagement is clear demonstration of the benefits and value of investing in energy-saving programs. Utilizing data platforms and advanced metering, coupled with post-upgrade financial appraisals can be effective at exhibiting to landlords the return on investment reaped through the energy savings achieved by these programs [50]. This extends to reduced operating expenses for landlords and minimized rental turnover, while increasing property values [161].

Strategies to resolve the split incentive barrier center around aligning tenant and owner incentives through financial inducements, efficiency standards, utilizing data and energy savings measurements, and improved landlord engagement (see separate term). Financial strategies to resolve split incentives include subsidies for efficiency upgrades [4], on-bill financing for master metered properties [164] and green leases [60]. Split incentive inefficiencies have been shown to account for 2% of domestic energy consumption and are responsible for shifting the burden of this cost toward low-income customers [164]. Resolution of split incentives promises $1.2 billion in savings for these customers through reduced maintenance and operational costs [52,164].

Renewables and Smart Grid

Smart Grid

Deployment of advanced metering infrastructure (AMI) has hastened in recent years. The benefits, challenges, and expense of AMI, or "smart grid", infrastructure presents a number of technical and market challenges for ensuring that the benefits of ratepayer investment in AMI extends to LMI consumers. LMI consumers have lower knowledge and support for smart grid overall [138]. Furthermore, LMI consumers may not be able to benefit from smart grid services, such as time of use rates, due to their typically low and flat load profiles [141].

While there are challenges, many potential benefits of the smart grid for LMI consumers have been identified. To date, consumers view power reliability as the greatest value of the smart grid [138]. Additionally, the smart grid may reduce societal energy costs over the long term, primarily because energy rates and prices will evolve to more precisely track the generation, transmission, and distribution costs.

For parties interested in helping LMI consumers to benefit from smart grid services, the focus has been education and engagement. Public meetings and customer service information centers can help to educate consumers on the benefits [127,141]

Renewables Policy

Reductions in the installed cost of solar have not led to a commensurate increase in LMI adoption [165]. Officials in several states have begun to reshape energy policy to provide assistance for LMI solar adoption [166]. New engagement and community development programs are needed, as well as continued policy support, in order to bring LMI consumers up to the adoption levels of more affluent consumers [167]. In at least two states, NY and CA, new policies are being launched to target market barriers specified to LMI consumers [168].

LMI Solar Access and Community Solar

As distributed solar systems have fallen in price and proliferated over the past decade, upfront costs have been a deterrent for most LMI consumers, blocking access to the numerous benefits of PV [97,167,169].

Community solar is an increasingly popular solution, allowing customers to purchase solar subscriptions from power systems developed offsite [97,127,150]. Numerous deployment models have been demonstrated with configuration options allowing utility, third-party, or community ownership of the system; various subscription products; and options for setting up metering and bill credits [97,127,150].

Community solar has several benefits. Since systems are aggregated, the price per watt is generally lower [3,150]. Consumers in multifamily residences, or who don't own their homes, can own part of an off-site system, which also permits more strategic siting of large systems [145]. Community solar is also being explored as a means to augment the benefits of other utility programs, like energy efficiency and zero net energy [3,110].

In many areas, RPS laws and rate structures haven't been adjusted to accommodate community solar [97]. LMI consumers still face difficulty participating in community programs due to credit requirements and other income factors [132].

Models are still evolving, and it's not clear how many community solar programs across the US which include program elements that facilitate LMI participation are active or in development , or how widespread enabling policy for LMI participation has been deployed. It is possible for utilities and third party lenders to provide financing options, in particular to eliminate the need for upfront payments [132]. Green banks can also help to reduce the burden of funding LMI community solar programs, credit underwriting, and rebates [132]. Longstanding programs have already started piloting new ideas, including programs from LIHEAP and HUD [132]. At a fundamental level, state and federal policy may be adjusted to promote approaches that facilitate tax and metering for community solar [110,132,165].

4.7. Natural Resources / Fuels

The disproportionate adverse effects of pollution and climate change on low-income populations are widely recognized [22,32,161]. These effects are exacerbated in particularly disadvantaged and vulnerable communities, including people of color [24,60], senior citizens, and the disabled [124]. Environmental attitudes among these communities are very closely aligned with the general population [138], and there is potential to weave climate and low-income policies together for amplified effect [159]. This includes intertwining renewable [47,124], energy efficiency [159], Clean Power Plan [159]/Carbon Tax [158], and pollution targeting policy goals with low-income programs to raise additional financial support and awareness of these programs. In contrast, several studies are cautious to attribute any environmental benefits to certain rate change programs, including time of use rates [170] and fixed charges [66], suggesting that they either adversely or negligibly affect pollution goals, while harming low-income populations. Two studies [126,170] also caution against targeting low-income populations for pollution reduction targets that are arguably impossible to achieve, potentially harming both environmental and energy poverty policy goals.

Energy use and water consumption are closely linked within the low-income population where domestic hot water consumption accounts for nearly 30% of energy use [56] and water is commonly kept running to prevent frozen pipes in cold weather regions [35]. There is a significant opportunity for energy efficiency programs that target both water and energy consumption to have a major impact of energy savings and energy burden [35,56].

The central argument over natural gas consumption among energy-poor communities focuses on whether its use as a fuel source positively or negatively impacts low-income communities. Natural gas advocates argue that fuel retrofits to lower-cost natural gas (especially in cold climates) lead to higher energy savings [94] and have minimal rebound effects [55] than electricity retrofits [37]. In juxtaposition to these claims, a pair of studies [144,171] argues that exposing low-income customers to the increased price volatility of natural gas is high risk and will have potentially negative consequences. As with other forms of energy use, it is observed that natural gas consumption is weakly correlated with income due to reduced efficiency in low-income communities [70], leading one study to examine the distributional effect of natural gas price reform to marginal cost pricing, determining that reform would have slightly negative consequences for the majority of low-income communities (except families with multiple children), although this can be potentially offset through needs-based programs such as LIHEAP [70].

4.8. Research Lacking

A number of important LMI research topics have not been sufficiently studied. Across the reports we analyzed, authors pointed to specific topics that need additional attention. In addition, it is clear that some important topics are scarcely studied, while other issues are nascent, and consistent findings have not yet fully formed.

More and better data on energy conservation behavioral impacts is needed [55]. Addressing this research gap should include focus on better understanding motives and barriers, as well as the effects of real-time usage data [72,137]. Greater understanding of LMI customer demographics, and the associations between customer types and program acceptance, response, and retention is required [172]. Comparison between program demographics and U.S. Census data could help to determine whether underrepresented groups are being adequately engaged [55,173].

Multifamily retrofit performance ranks high among areas for increased focus [56,60,137,174]. Time of use rates [56,119,122,135,170] and prepay programs [146] both contentious and relatively new entrants in the U.S. electricity market are understudied. Rebound effects are an interesting opportunity for additional LMI focus. Better understanding on the magnitude of rebounds from LMI consumers is necessary; however, the extent to which higher-than-average rebound effects coincide with enhanced well-being also needs to be explored [88,90].

5. Takeaways and Conclusions

The landscape of recent LMI research is checkered. Studies point to opportunities to better serve the energy needs of LMI populations through focused and collaborative efforts of the power sector. Some areas of research are little understood, while for others that have been studied, like prepay programs, insufficient results from demonstration are available. On the other hand, research has developed rich insights upon which further exploration may build.

Key characteristics of LMI consumers have been explored as part of various research objectives. Studies that examined energy burdens, for instance, explored interactions between consumer characteristics and the market, similar to studies that sought to understand LMI consumer responses to prices or market intervention. Given their importance, however, LMI consumer profiles have been understudied. We need greater understanding about how LMI consumers are unique from non-LMI consumers, and how they are responsive to and affected by the power sector.

A number of LMI consumer characteristics stand out as timely and important; for instance, housing type and quality are major factors contributing to energy burdens. These are also relatively fixed attributes, which limit the opportunities available to ameliorate energy-related hardships. Combinations of low income, high energy demand, and poor housing quality can force difficult tradeoffs between essential needs. We view the housing context as an "upstream" problem, because many "downstream" challenges become more difficult to address due to the typical condition of LMI housing. Downstream challenges affected by housing context include energy efficiency cost-effectiveness, AMI-service participation, and vendor-led services (for instance, where contractors play a major role in educating customers).

Financial barriers, especially lack of upfront capital, constitute another upstream problem. Many areas of the utility service model predominantly follow buy-down and rebate models that help consumers afford upgrades that reduce energy bills and improve indoor health. Such programs allow utilities and consumers to meet in the middle and share the cost of mutually beneficial upgrades. For most LMI consumers, however, the logic behind meeting in the middle fails. Most LMI consumers have no discretionary income, rendering these mainstay programs to be of little benefit. The notion that LMI consumers have few funds to spare is reinforced by studies showing that rebound effects following energy efficiency upgrades are higher among LMI consumers. These studies argue that this is because LMI consumer consumption is significantly lower than their demand. And while some utility or grid services, such as demand response, have been shown to yield strong results when properly tailored to LMI consumers, little experimentation has been done to build out services with LMI consumers in mind.

Nearly five million Texans reside in households below the poverty line, and another five to six million live in households that earn an income above the poverty line but below $50,000 annually. Together, these two population segments make up approximately 40% of Texas, the second most populous state in the U.S. The power sector service model needs to be tailored to better serve LMI consumers, but additionally because the market potential of doing so carries a major value proposition. The estimated U.S. energy savings potential associated with LMI behavior change alone is $13 billion [62], and a further $16 billion of savings potential has been attributed to efficiency retrofits of multifamily buildings [83].. LMI demand response program models have been proven in concept, and the opportunity to scale LMI demand response profitability can be accelerated by broader commitment and coordination across the power sector.

There are opportunities to scale up profitable LMI services. There are also opportunities reimagine how rates and services are constructed, thereby benefitting LMI consumers. Non-energy benefits (NEBs), for instance, could diversify and improve the spectrum of program offerings. Many studies argue in favor of including non-energy benefits to broaden the available toolkit of interventions from which programs can draw.

Reinventing customer engagement is the most glaring and broadly agreed upon opportunity to improve service to LMI consumers. From program design to needs assessment, the need for customer engagement strategies better tailored to LMI populations is a consistent theme across the research areas we explored. Numerous studies found that participation and performance improve when a tailored LMI strategy is brought to bear. Customer engagement is key across numerous areas of the power sector – customer satisfaction, program participation, and outage reporting, to name a few. Most studies, however, convey that not enough is known about how to engage LMI consumers, this is a gap future TEPRI research aims to fill. Lack of fundamental understanding, we assume, impacts the cost and difficulty of tailoring engagement strategies to LMI consumers. Returning to the contention at the beginning of this section, engagement strategies will be most effective when nested within solid understanding of LMI profiles, and the ways in which LMI consumers respond to and interact with the power sector.

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7. Appendices

7.1. Methodology.

- Stage one – Piloting. During this phase, we identified dozens of organizations that published relevant research during the observation period (2002-2016). We solicited input from more than a dozen electricity market research and program administration experts regarding key organizations to consider (see Appendix 7.2 for a list of organizations).

  We downloaded reports from the websites of organizations on the list, and reviewed each (roughly 100 reports) to identify content characteristics to inform our search criteria and analysis approach. In particular, we developed constraints and definitions to narrow our search to content of greatest interest to the project.

- Stage two – Content search. We developed a manual algorithm to identify content to be considered as sources for analysis. We again informally surveyed individuals with expertise in the U.S. electricity market and developed an exhaustive set of search terms. We identified a total of 184 unique search terms, across 49 groups. The search term was the third search string element. Search terms were limited to unidimensional, single or multi-word statements that related to a potential LMI research area.

  Search terms were combined with two constants to produce 184 unique Boolean strings. Each string contained two constants, "low-income" and "energy", anchoring results to the area of interest.[h] Every search was executed through Google's search engine.[i] For every string, we reviewed the first 50 results. Results were collected and archived if they met the standard set for analysis; results must:

  - Be or reference a downloadable report, white paper, or study;
  - Discuss a single study, multiple studies, or meta-analysis of studies;
  - Discuss research conducted in the U.S., using data developed in the U.S., or representing U.S. consumers or other market actors;
  - Be publicly available for no charge (E.g., not behind a paywall); and

[h] At the outset of the search process we piloted substitutes for the constants "low-income". We compared the results of identical searches where we substituted "low-income" for "underserved" and then for "poverty". We found "low-income" to be the most suitable search string constant.

[i] At the outset of the search process we reviewed suggestions and best practices for reducing search results bias when using Google Search Engines. There appear not to be many hard and fast practices, but we found consistent recommendations that researchers log out of any Google profiles before conducting searches. We followed this practice when implementing our content search.

- Be published between 2002 and 2016.

Reports downloaded from the search results were stored in the cloud-based qualitative analysis program Dedoose. Sources were given attributes defining the publishing organization and funding organization (where applicable).

- 〉 Stage three – Analysis. To analyze the topic content, we needed first to develop a taxonomy of topic definitions from the ground up.[j] The taxonomy is developed by building topic definitions nested within groups. The full taxonomy is multi-level. The final topic definition, known as the terminal topic, contains the native text collected from each source. The full taxonomy creates a logic tree of nested topics, for which each topic is given a "code" that summarizes the topic in few words. The code tree is called our coding scheme.

To develop the coding scheme, we first piloted roughly 100 randomly sampled sources. We thoroughly reviewed the sources to create high level topic categories, and captured clauses surrounding each unique topic. At this stage, we also created a definition to limit the content we considered topics. Content within a source was considered a topic if it described the research focus. We then derived the initial set of high level codes as the basis of our coding scheme. We reviewed the remaining sources, coding all topics under the high-level codes. When complete, we created subsidiary codes to further categorize the content captured by the high-level codes, generating the full taxonomy.

As a final step, we reviewed the fully coded content and assessed the salient aspects of each topic area. Excerpts for each terminal code were queried and collated. For each terminal topic, we summarized perspectives and framing of research, creating an overview of the topic space.

7.2. TEPRI Qualified LMI Research Organizations

We developed a list of organizations that have contributed significantly to the body of research energy poverty research. Firms included in the list met the following conditions:

- 〉 Published more than one study or report focused on energy poverty between 2002-2016, and
- 〉 The work was generated, enhanced, or provided greater visibility as a result of the organization.

[j] Our ground up approach separates any relation to the search terms used to generate the reviewable sources.

〉 A number of organizations generated unique, valuable insights with original empirical research, or contributed a large number of useful studies or reports to the body of energy poverty work. Organizations meeting these criteria are indicated in bold text

- **AARP Public Policy Institute**
- **American Council for an Energy-Efficient Economy (ACEEE)**
- Alliance to Save Energy (ASE)
- American Public Power Association
- **Applied Public Policy Research Institute for Study and Evaluation (APPRISE)**
- Arizona State University
- Association for Energy Affordability (AAE)
- Lawrence Berkeley Lab
- **Brattle Group**
- California Institute for Energy & Environment
- **California Public Utility Commission (CPUC) Ratepayer Advocates**
- Carnegie Mellon University
- Center for American Progress
- **Center for Children in Poverty (Columbia)**
- Center for Community Change
- Center for Sustainable Energy
- Center on Budget and Policy Priorities (CBPP)
- CERES
- Children's Health Watch
- Citizens Energy Corporation
- Collaborative Efficiency
- Congressional Research Service (CRS)
- Consortium for Energy Efficiency (CEE)
- **Distributed Energy Financial Group**
- Department of Energy
- Environmental Defense Fund
- Energy Efficiency for All
- **Energy Institute at Haas (UC-Berkeley)**
- **Elevate Energy**
- **Economic Opportunity Studies**
- Environmental Protection Agency
- Electric Power Research Institute (EPRI)
- George Washington Solar Institute
- Global Green USA
- Green and Healthy Homes Initiative
- Grid Alternatives
- Institute for Electric Efficiency
- Innovation Electricity Institute
- International Energy Agency
- **Interstate Renewable Energy Council (IREC)**
- **Joint Center for Housing Studies (Harvard)**
- Low-Income Forum on Energy (LIFE)
- National Action Plan for Energy Efficiency Leadership Group
- **National Association of Regulatory Utility Commissioners (NARUC)**
- **National Energy and Utility Affordability Coalition (NEUAC)**
- National Energy Assistance Directors' Association (NEADA)
- **National Regulatory Research Institute**
- National Rural Electric Cooperative Association (NRECA)
- National Community Action Foundation
- National Consumer Law Center
- Northwest Sustainable Energy for Economic Development
- National Resources Defense Council (NRDC)
- National Renewable Energy Lab (NREL)
- New York State Energy Research and Development Authority (NYSERDA)
- **Oakridge National Lab (ORNL)**
- Penn State
- Public Utility Law Project
- **Regulatory Assistance Project (RAP)**
- Resources For the Future
- Rocky Mountain Institute (RMI)
- **Smart Grid Consumer Collaborative (SGCC)**
- Stanford Precourt Center
- Southwest Energy Efficiency Project (SWEEP)
- **Synapse Energy Economics**