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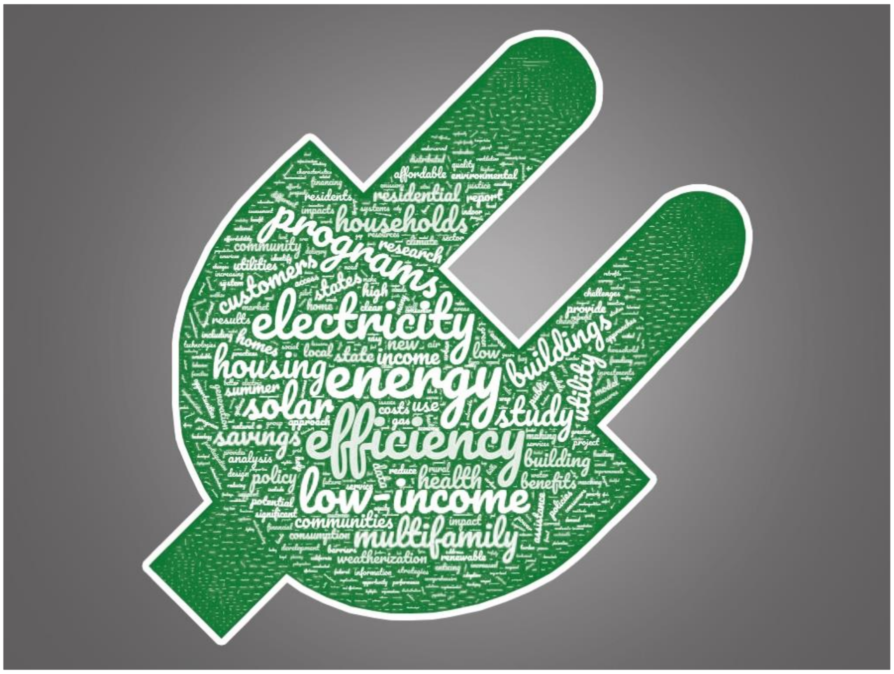
Low-Income Energy Affordability: Conclusions from a Literature Review



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Date: March 2020

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Energy & Transportation Science Division

LOW-INCOME ENERGY AFFORDABILITY: CONCLUSIONS FROM A LITERATURE REVIEW

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CONTENTS

ACRONYMS

AMI	Area Median Income
ARRA	American Recovery and Reinvestment Act
CDC	Center for Disease Control
DOE	U.S. Department of Energy
EECLP	Energy Efficiency and Conservation Loan Program
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicles
FERC	Federal Energy Regulatory Commission
FPL	Federal Poverty Level
HHS	U.S. Department of Health and Human Services
HUD	U.S. Department of Housing and Urban Development
IRP	Integrated Resource Plan
LIHEAP	Low Income Home Energy Assistance Program
LIHTA	Low-Income Housing Tax Credit Program
MSA	Metropolitan Statistical Area
MOU	Memorandum of Understanding
NASCSP	National Association of State Community Services Programs
NGO	Non-governmental organization
NCHH	National Center for Healthy Housing
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
RECS	Residential Energy Consumption Survey
RGGI	Regional Greenhouse Gas Initiative
SDG	Sustainable Cities and Communities
SEP	State Energy Program
SMI	State Median Income
SPM	Supplemental Poverty Measure
UNDP	U.S. Development Program
USDA	U.S. Department of Agriculture
TVA	Tennessee Valley Authority
WAP	Weatherization Assistance Program

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ABSTRACT

This paper examines the persistent problem of high energy burdens among low-income households, based on a review of more than 180 publications that pointed to several promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, and behavioral economics. using an equity and affordability lens. Even after decades of weatherization and bill-payment programs, low-income households, on average, continue to spend a higher share of their income on electricity and natural gas bills than any other income group. Energy burden for low-income households is not declining, and it remains persistently high, particularly in the South, in rural America, among minority households, and those with children and elderly residents. On a per household basis, utility companies spend less on energy-efficiency programs for low-income households than for other income groups. In addition, government and utility programs that promote rooftop solar power, electric vehicles, and home energy storage are largely inaccessible to low-income households. Our review identifies promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, behavioral economics, data analytics, advanced information and communication technologies, and grid resiliency. Scalable approaches require linking implementing agencies, programs and policies to tackle the complex web of causes and impacts on low-income households with high energy burdens.

1. INTRODUCTION: GOALS, SCOPE, AND STRUCTURE OF LITERATURE REVIEW

1.1 GOALS OF THE LITERATURE REVIEW

Energy drives the U.S. economy and impacts nearly every dimension of modern society; it is an imperative of daily existence. When access to energy becomes difficult, the burden is felt in every facet of life – housing, mobility, health, work, education, and much more.

Since the 1970's introduction of major low-income energy programs in the U.S., the nature of household energy consumption has evolved. For decades, the energy consumed by a typical household increased as suburbanization and sprawl enabled homes to grow, and affluence and innovation made central heating and cooling systems almost universal. Appliances multiplied, and "plug loads" proliferated with the creation of new low-voltage AC devices: computers, telephones, hi-fi's and more (Nordman and Sanchez, 2006). In contrast, low-income households continued to occupy much of the energy inefficient housing stock in the older core of American cities.

Over time, these trends have evolved. Increasingly congested urban areas have motivated moves back to inner cities, re-densifying and gentrifying older neighbourhoods, sometimes at the expense of affordable housing. This has created a new geography of suburban poverty with issues of energy affordability that have not yet been documented. At the same time, many low-income households in rural communities have chosen to maintain their social networks and ways of life, and have not moved to urban areas where jobs and property values have been growing more rapidly. In rural areas where the economy has been stagnant and the housing stock is older, low-income energy burdens are worsening.

Nationwide, innovations continued to transform home energy use, with more efficient appliances (furnaces and heat pumps, refrigerators, etc.), smart thermostats, solid state lighting, low-emissivity windows, and foam insulation – reducing the energy consumed by individual households. Rooftop solar panels have reached "grid parity" in some parts of the U.S.[1], and soon home energy storage systems and electric vehicles (EVs) will enable households to arbitrage their energy assets.

In the midst of these transformations, it is time to review what we know about the energy burden of low-income households:

- How have low-income energy burdens changed over the past decade?
- How have they been affected by energy programs, policies, and technology trends?
- What opportunities offer the greatest promise to reduce the energy burden of low-income households, as the U.S. continues its transition to a more efficient and renewable energy system?

To answer these questions, we summarize the knowledge embodied in the last decade of literature focused on low-income energy burdens in the U.S. Many entities across the U.S. – chiefly utilities and federal and state agencies, but also nonprofits and religious organizations, as well as cities and community organizations – work to save energy and reduce the energy costs of

[1] https://www.greentechmedia.com/articles/read/gtm-research-20-us-states-at-grid-parity-for-residential-solar#gs.7enug2

low-income households. As a result, a substantial body of literature has examined the design and impacts of these programs and policies. Other research has produced energy-focused case studies of low-income communities, surveys of the energy behavior of low-income households, and accounts of energy bills in the overall expenditures of low-income households. With the proliferation of information on the internet, this decade of literature is immense. Our literature search methodology is described in Section 1.3.

This paper begins by characterizing the magnitude, causes, and impacts of the energy burden currently experienced by low-income households in the U.S. It then describes the multiplicity of energy programs and policies that impact low-income energy burdens. Program design, implementation, participation rates, and investment levels are described in Section 3. This is followed by a summary of the cost-effectiveness and impacts of the programs, which enables estimates of the remaining potential in Section 4. Attention then turns to identifying major gaps and opportunities that energy programs and policies could address in the future (Section 5), and we end with conclusions about opportunities to scale up these impacts.

1.2 THE ENERGY EQUITY LENS

Increasingly energy scholars are focusing on the importance of equity in the transition to a smarter and greener energy economy. The rapid uptake of new technologies has the potential to benefit some and harm others, to the extent that resources, jobs, and capital are redistributed. Depending on the sources and distribution of financing, the design of policies and programs, and the location of infrastructure and facility investments, low-income households may benefit or lose going forward. And if low-income households "lose," all households lose, because there will be negative effects for all Americans if segments of society are left behind. Overall, the U.S. is experiencing a growing wealth disparity between low-income households and more affluent Americans (Curti, Andersen, and Wright, 2018). Living in communities of color, indigenous populations, and immigrants typically means more limited access to resources. This intersection of race, ethnicity, and class needs to be considered when designing effective low-income energy programs and policies (Reames, 2016; Sunter, Castellanos, and Kammen, 2019).

The environmental justice community has highlighted equity issues in the debate about environmental externalities from the consumption of energy. Due to their lower per capita energy consumption, low-income households contribute proportionately less to local and global air pollution. At the same time, they tend to suffer disproportionately more from the impacts of poor air quality (National Research Council, 2010a, b). These past trends highlight the possibility that the transition to increasing use of renewable energy underway for many states and communities could cause energy justice to unfold in similarly inequitable ways because of long-standing and uneven power dynamics (Healy and Barry, 2017). Equity is increasingly being considered in discussions of energy program design (Curti et al., 2018; Massetti et al., 2017). The literature on environmental equity concerns have enumerated energy policy linkages to health outcomes, access to cleaner air, transportation and other public services which contribute to households' overall well-being (Jenkins et al., 2016; Massetti et al., 2017). In addition, researchers also recognize that policies to decarbonize the energy sector, can, in fact, worsen disparities due to their disproportionate effects on economically weaker segments of society (Monyei et al., 2019).

Formal discussions of equity typically distinguish between procedural equity that deals with "inclusion" and distributive equity that deals with "access" (Curti et al., 2018). In addition, this paper also considers intergenerational equity as an important dimension of energy affordability. Each of these dimensions is discussed below in the context of low-income energy programs. Additional dimensions often refer to redistributive equity (fairness in the punishment of wrongs), structural equity (prevention of the chronic, cumulative disadvantage experienced by subordinated groups), and transgenerational equity (avoidance of unfair burdens on future generations) (Franklin and Osborne, 2017).

1.2.1 Procedural Equity (Inclusion)

Procedural equity is the idea of fairness and transparency of the processes that allocate resources and adjudicate disputes. Connected to the desire for due process, one aspect of procedural equity is related to administrative and legal proceedings. In some instances, courts of law have demanded an equitable distribution of resources. As one example, a court settlement of an EPA case against the Tennessee Valley Authority involving air pollution violations involved the creation of an energy-efficiency program for low-income customers.[2] The idea of procedural equity can also be applied to non-legal contexts in which some process is employed to resolve conflict or divide benefits or burdens. Others emphasize "inclusion" as a key component of procedural equity: "inclusive, accessible, authentic engagement and representation in the process to develop or implement programs or policies" (Curti et al., 2018, p. 9).

Economically disadvantaged communities across the country are amplifying their voices to ensure that the transition to increasing use of energy efficiency and renewable energy considers their needs. For example, Goldberg and McKibbin (2018) describe how the Future Energy Jobs Act in Illinois materialized with the help of a coalition of interest groups, increasing investment in energy efficiency and targeting economically disadvantaged communities. Similarly, advocates from the environmental, affordable housing, energy, and low-income communities in Pennsylvania organized a collaborative advocacy that drove improvements to low-income energy-efficiency policy across the State. Their work drew on the skills, expertise, and resources of multiple disciplines, and prioritized the multiple benefits that energy efficiency provides for low-income households (Grevatt et al., 2018).

1.2.2 Distributive Equity (Access)

Distributive equity refers to fairness in the distribution of rights or resources. In his *Theory of Justice*, John Rawls (1971) claims that one's place of birth, social status, and family influences are matters of luck that should not unduly influence the amount of benefits we receive in life. The goal of distributive equity is to limit the influence of luck so that goods are distributed more fairly and to everyone's advantage. This line of reasoning has been extended by many to argue that distributive equity is achieved when programs and policies result in fair distributions of benefits and burdens across all segments of a community, prioritizing those with highest need (Curti et al., 2018, p. 9).

Across the country, energy-efficiency programs, special rates for electric vehicles, and net metering of solar rooftop installations are paid for in part with low-income ratepayer funds, but do not provide commensurate benefits to low-income ratepayers who do not have the resources to take advantage of these programs. If the energy industry, government agencies, NGOs and

[2] https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/Air%20Quality/EPA%20Mitigation%20Projects/Smart%20Communities%20-%20Extreme%20Energy%20Makeovers%20FAQ.pdf

nonprofits do not address these unintentional consequences, low-income households will continue to suffer disproportionately from high energy burdens, failing most tests of distributive equity (Chant and Huessy, 2018). Carley et al. (2018) also draw the same conclusion based on their assessment of disparities in vulnerability across U.S. counties using the renewable portfolio standard.

1.2.3 Intergenerational Equity

Intergenerational equity adds a time dimension to the equity discussion by considering community obligations to future generations. Actions that serve to increase rather than limit the development options of future generations can be said to improve intergenerational equity (Norton, 2005). In the field of clean energy, intergenerational equity frequently involves deliberating which aspects of the present should be maintained or changed for future generations. Most energy efficiency and renewable energy programs reduce CO_2 emissions and, as a result, contribute positively to intergenerational equity in some ways. How these programs may impact the social and economic contours of communities across generations has received much less emphasis.

1.3 THE CONTEXT: MULTIPLE STAKEHOLDERS IN THE LOW-INCOME HOUSING MARKET

Numerous decision-makers and stakeholders influence the energy efficiency and renewable energy consumption of low-income housing (Figure 1.1). This highly fragmented affordable housing market challenges efforts to improve low-income energy affordability. Government agencies have administrative and regulatory roles that influence each of these stakeholders to varying degrees. In terms of word counts, energy utilities are mentioned most often in the abstracts of the 183 publications examined in this review. Local non-governmental organizations (NGOs) and community-based groups are also key stakeholders based on this tally. At the other extreme, the terms “building manager” and “property manager” do not appear in the 183 abstracts, and “landlord” and “property owner” are mentioned only 10 times, indicating that these stakeholders have received limited analysis in this body of literature. While the literature describes the landlord/tenant split incentive and the difference between renter and homeowner investments in energy-efficiency, there is little analysis of the nature of landlords operating in the low-income housing market, despite our assessment of the influential roles they play. Figure 1.1 provides a framework for understanding how current programs and policies operate and how they can be leveraged to provide a more effective and coordinated system of assistance.

1.4 SCOPE AND STRUCTURE OF LITERATURE REVIEW

A search of the peer reviewed published literature was conducted along with a search of the grey literature of more informal materials. For the peer reviewed literature, the Web of Science bibliography was searched. The Web of Science is a service provided by Thomson Reuters and Clarivate Analytics. The service curates and compiles databases on citations for several academic disciplines. The aggregate citation and publication data can then be used in performing comprehensive literature searches and analyzing the search outcomes.

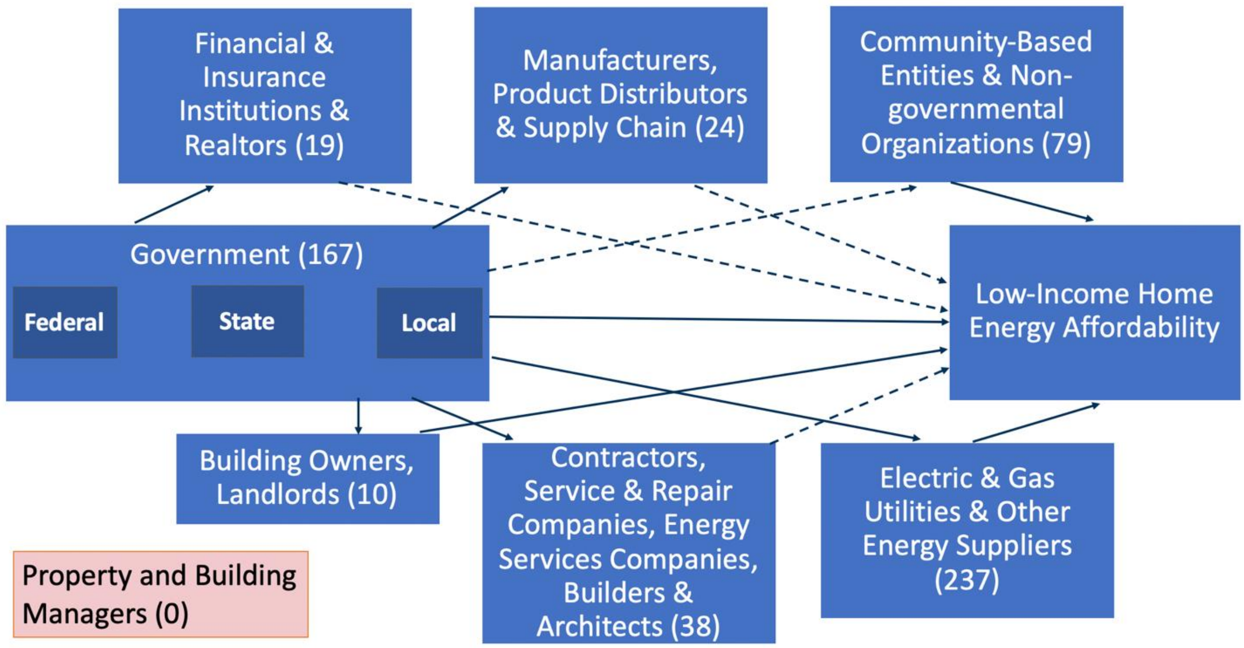

Figure 1.1. The array of stakeholders in the fragmented low-income housing market.
(Source: Authors)

Note: Numbers in parentheses are the frequency that stakeholders are mentioned in the abstracts of 183 publications examined for this review. Solid and dashed lines represent strong and weak connections, respectively.

A search protocol was established using a syntax of keywords that included synonyms of three attributes: (1) poverty and low-income households, (2) energy efficiency and solar energy, and (3) evaluation and data analysis. All three dimensions were required. In addition, at least one author had to be from the U.S., and the papers had to be published in the 2010-2019 timeframe. The resulting 270 peer-reviewed publications were “culled” for out-of-scope citations and also “mined” for additional references as the citations embedded in the original 270 publications were examined. This process produced a curated set of 171 publications. Several seminal references published earlier than 2010 are also cited in this report.

A Delphi approach to ensure consideration of the associated grey literature – including conference proceedings, trade association documents, and workshop presentations. In some instances, for instance, technology, program implementation, and policy innovations are so recent that the published literature has not yet addressed them.

The technology scope of this review is broad. Energy efficiency is a core technology of interest, referring to technologies, materials, and practices that require less energy to deliver a given service, such as heat, light, and warm water (Brown and Wang, 2015). Solar photovoltaic systems are also included in the technology scope, as well as electric vehicles, home storage, and microgrids because they too, can help to reduce energy burdens.

To manage and archive this vast information resource, an annotated bibliography of the literature reviewed in this paper is also available (Lapsa, Brown, and Soni, 2020).

While the scope is national, the review also highlights how geography, race, ethnicity, culture, health, and age create unique circumstances. Cities, suburbs, rural areas, island territories, and Indian reservations all offer different challenges and solutions. Low-income families with children and the elderly and disabled have different needs for energy and face different challenges to reduce their utility bills. Nevertheless, principles associated with successful programs and policies do emerge. In each section, we also summarize the key findings based on the dominant view in the literature that we examine. These findings are then summarized and organized into conclusions in Section 6, based on common themes and the preponderance of evidence from the literature review.

2. ENERGY BURDEN OF LOW-INCOME HOUSEHOLDS

Low-income households in the U.S. are diverse, as are their patterns of energy consumption. In this section, we describe alternative measures of energy burden, the energy consumption patterns of low-income households, how these patterns have changed over the past decade, and the causes and effects of high energy burden among low-income households.

2.1 MEASURING THE EXTENT OF THE BURDEN

To understand low-income energy burdens, it is important to examine the metrics used by analysts to characterize the energy consumption patterns of low-income households.

2.1.1 Variable and Inconsistent Definitions

Finding: Variable and inconsistent definitions and metrics are used to describe the energy consumption patterns of low-income households. The extent and nature of energy burden, and the estimated impact and value of solutions, depend upon the metrics used.

The term "household energy burden" has become a dominant construct used by analysts working on low-income energy issues in the U.S. Early and subsequent research conducted for DOE by Oak Ridge National Laboratory (ORNL) (Eisenberg, 2014) and Economic Opportunity Studies, Inc (Power, 2008) used energy burden as a means to characterize the U.S. population in need and to inform program and policy. The term is generally defined as the share of a household's income that is spent on energy utilities (Drehobl and Ross, 2016). There are two parts to this definition – the numerator provides a measure of energy expenditure by the households, reflecting energy consumption and rates; the denominator is a measure of household income or budget.

Household energy expenditure is usually measured by looking at the total spending on household utility bills for heating, cooling, and other home energy services (Berry, Hronis, and Woodward, 2018). Most energy burden studies do not analyze household spending on transportation energy.

Household income or budget is also measured in a variety of ways, using different benchmarks. These include, the Federal Poverty Level (FPL), State Median Income (SMI), Area Median Income (AMI), and household budgets. The Supplemental Poverty Measure (SPM)[3] conducted by the Census Bureau measures household income after including different sources of financial support. Accounting for households that receive different support payments and reducing them from the household income levels increases the level of poverty across most categories. The income benchmarks used to qualify households for different energy assistance programs can influence the program's energy savings (Hoffman, 2017).

In fiscal year (FY) 2014 (October 1, 2013-September 30, 2014), the average annual weather-normalized expenditure for low-income households (at or below 200% of the federal poverty level) was estimated to be $1,851 (Eisenberg, 2014, p. 10). About 39% of this ($721) was estimated to be for primary heating and cooling expenses. Based on the same source, non-low-income households spent $2,284 on residential energy in FY 2014, with $906 (40%) spent for primary heating and cooling. Based on the 2009 Residential Energy Consumption Survey

[3] https://www.census.gov/prod/2012pubs/p60-244.pdf

(RECS) and inflation adjustments, the average income of low-income households in FY 2014, was estimated to be $18,773 compared to $71,755 for non-low-income households. The resulting household energy burdens were estimated to be 16.3% for low-income households compared to 3.5% for non-low-income households (Eisenberg, 2014, p. 10).

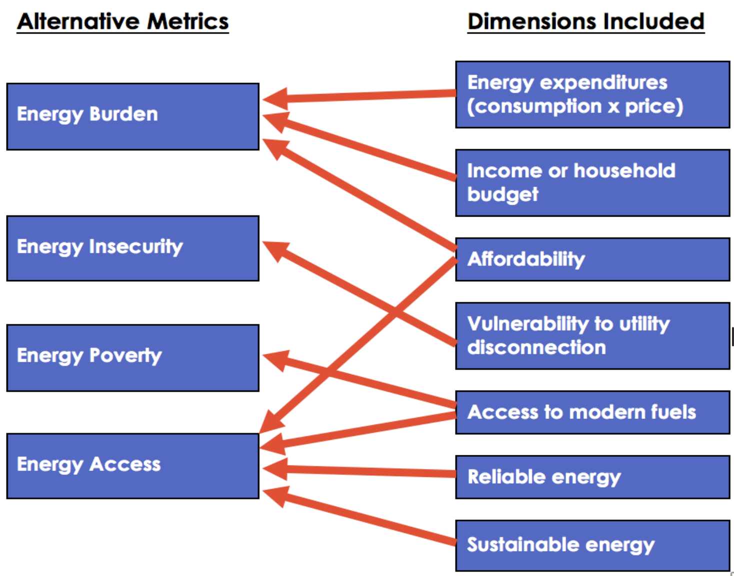

Figure 2.1. Scope of energy burden and related definitions.
(Source: Authors)

Based on household energy burden, Colton (2011) defines "energy poor households" as those spending more than 6% of their income on meeting energy costs. The premise for this benchmark is that a household should not spend more than 30% of its income on housing expenses, and the utility costs should not exceed 20% of these expenses. This threshold is often used for comparison purposes and to estimate the "affordability gap" (Fisher, Sheehan, and Colton, 2013). A range of thresholds has also been developed. In a study for the State of Colorado, Cook and Shah (2018a) distinguished between "energy stressed" households with energy burdens of 4-7%, "energy burdened" households with 7-10% energy burdens, and "energy impoverished" households with energy burdens greater than 10%.

A second construct – "energy insecurity" – refers to the uncertainty that a household might face in being able to make utility bill payments (Berry et al., 2018), which can ultimately result in being disconnected from energy services either permanently or temporarily (Verclas and Hsieh, 2018). Elnakat, Gomez, and Booth (2016) and Ross, Jarrett, and York (2016) document that the incidence of energy security varies by region with the highest rates in the South.

In contrast, the term "energy poverty" generally refers to living in a home that does not have access to enough energy to meet their essential needs. More functionally, it is described by the U.N. Development Program (UNDP, 2005) as the "inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset." Modern energy services are crucial to human well-being. About half a million Americans live without access to basic electricity services, and a majority of these households reside in U.S. territories or on American Indian reservations (Begay, 2018b; EIA, 2000).

In the international literature, “energy access” is a common term, and is recognized in the Sustainable Development Goals adopted by the United Nations in 2015. Further, the first target of the Sustainable Cities and Communities Goal (SDG 11) is access to adequate and affordable housing with basic services, which includes affordable utilities. SDG 7 aims to ensure access to affordable, reliable, sustainable and modern energy to all by 2030. Affordability and reliability are both critical components of energy burden analysis in the U.S. context, where high levels of access to energy exist as compared to other countries, but many groups face high energy burdens. SDGs were adopted in 2015 at the U.N. Sustainable Development Summit in New York. The SDGs are a continuation of the global pursuit of sustainable development which was first recognized in the 1992 Earth Summit in Rio de Janeiro through the Adoption of Agenda 21.[4]

In sum, multiple definitions are used to discuss low-income energy burdens, to qualify households for assistance in different programs, and to estimate the potential for future energy bill reductions (Hoffman, 2017). This is problematic because the extent and nature of the energy burden problem depends on the definition used (Figure 2.1).

- The problem of energy burden and vulnerability is more widespread when measured by a combination of indicators (Lin, 2018b), such as income poverty combined with hardship making bill payments (Berry et al., 2018).
- GIS mapping documents that using different definitions can lead to higher or lower estimates of energy burden in different types of regions; while income and energy poverty are highly correlated, the problem of high energy burden among the income poor is more pronounced for those living in rural areas (Lin, 2018b).
- Using a range of definitions of income and spatial densities to provide estimates of potential savings, Hoffman (2017) demonstrates that total savings and their distribution can vary greatly based on the definition of low-income households and communities.

2.1.2 Magnitudes, Distributions, and Trends

Finding: Energy burden is higher among low-income households than other income groups. The average energy burden of low-income households is not declining, and it continues to be high in particular geographies and socio-economic groups. Low-income households spend a higher proportion of their income on energy bills than any other income group (Eisenberg, 2014; Berry et al., 2018), spending on average three times more of their income on energy bills than higher income households (Drehobl and Ross, 2016). This is true, even though low-income households consume less energy per capita than other households. Evidence indicates that participants in the Weatherization Assistance Program (WAP) managed by the U.S. Department of Energy (DOE) have even higher energy burdens (Eisenberg, 2014). These high burdens were strong motivators to apply for services: 43% of respondents in one study reported this as a motivating factor (Rose et al., 2015, p. 22). This is consistent with the finding by Tonn, Rose, and Hawkins (2015, p. 5) that prior to weatherization, 65% of survey respondents reported that it was hard or very hard to pay for energy bills, while post-weatherization, the percentage dropped to 49%.

[4] https://sustainabledevelopment.un.org/outcomedocuments/agenda21

High energy burdens produce energy insecurity. Residential Energy Consumption Survey (RECS) data for 2015 indicate that 31% of all U.S. households experienced some form of energy insecurity – often foregoing food and medicine in order to pay an energy bill. These rates were particularly high in mobile homes (58%) and in apartments in buildings with 2-4 units (46%) (Berry et al., 2018). In 2015, nearly seven million households had their access to heat interrupted at least once, and six million lost access to air conditioning at least once (Verclas and Hsieh, 2018).

Energy security is significantly more problematic for low-income households. Based on a national survey in 2015, 40% of households with income below $50,000 find it difficult to pay their energy bills at least "once in a while".[5] In 2017, one-third of consumers with household incomes of less than $50,000 had trouble paying their electric or heating bills at least sometimes, 7% more than in 2016, despite the stronger economy (Treadway, 2018). Utility disconnections are difficult to track because most states do not require utilities to record these numbers. However, there is an exception in some states where utilities file these numbers with the Public Utility Commissions (Verclas and Hsieh, 2018). The number of disconnections appears to be increasing in at least two states. In Texas, the number of recorded disconnections increased by 64% between 2010 and 2016, and in California, the numbers tripled between 2006 and 2016 (Verclas and Hsieh, 2018). The authors further note that low-income households (with incomes less than $20,000) were almost three times as likely to face energy insecurity as households with income greater than $60,000. A simple but nonetheless meaningful definition of energy access is the ability to get utility service, which is impacted by the disconnection practices and policies of utilities.

Just as energy security is not improving, the average energy burden of low-income households is also not declining. To assess trends and geographic variations in energy burden, Fisher, Sheehan and Colton define the home energy affordability gap as the difference between actual home energy bills and affordable home energy bills.[6] The actual bills are calculated as a function of energy usage, housing, and weather characteristics. As noted earlier, the affordable burden is set at 6% of the household's income. The gap is calculated at a county-by-county and state-by-state level, for different segments of the low-income populations starting at 50% and going up to 200% of the household federal poverty level. Based on updated national estimates, the home energy affordability gap index for the U.S. in 2018 was 134.4 (compared to the indexed value of 100 in 2011).[7] [8] In monetary terms, this is equivalent to $51.8 billion. The report also provides a summary of this distribution across census regions. The Mountain region had the highest Home Energy Affordability Gap Index at 284.6. This translates to $3.7 billion in 2018, compared to $1.3 billion in the base year, 2011.

At the same time that these indicators show that neither energy affordability nor energy security are improving, program evaluations document clearly that the energy affordability for the millions of homes that have received weatherization and energy-efficiency services has, in aggregate, improved (see Section 4). The average burden of low-income households overall has

[5] http://defgllc.com/news/article/how-well-are-you-reading-your-low-income-customers/#/
[6] http://www.homeenergyaffordabilitygap.com/01_whatIsHEAG2.html
[7] http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html
[8] http://www.homeenergyaffordabilitygap.com/downloads/2018_Released_Apr19/HEAG2018%20Regional%20Fact%20Sheets.pdf

not declined largely because only a fraction of the total eligible population has received such services.

The energy consumption patterns of low-income households vary with gender, age, race, education, health and disability status, as well as cultural attributes and occupations of members (Tonn et al. 2015, 2015b). Elnakat et al. (2016) found that households in zip code areas where the median age of the household head was less than 30 years, used significantly less energy per capita than zip code areas with median ages above 40 years. Zip codes with a higher percentage of high school graduates also had higher levels of energy consumption.

Geography is also important: household energy patterns vary widely across highly urbanized areas (Porse et al., 2016), suburbs (Verclas, 2018), rural and remote locations (Souba and Mendelson, 2018; Lin, 2018b; Ross, Drehobl, and Stickles, 2018; Begay, 2018a, b) and climate regions (Ross, Jarrett & York, 2016). Many low-income households have experienced generations of the poverty cycle, especially the chronically unemployed including disabled individuals who are dependent on public assistance or charitable support for survival. Others have recently experienced income declines, due to shifting job opportunities and retirement from the workforce. Some have chosen a low-paying profession such as artists, writers, and community activists. Still others are unskilled or semi-skilled, working in low-wage jobs in retail, hospitality, and health services. Energy decision making varies across all of these groups (Schwartz, 2014).

The problems of high energy burden and insecurity are more severe in minority households and those with children and older residents (Berry et al., 2018). Hernandez, Aratani, and Jiang (2014) found that black households with children were more likely than any other group to experience energy insecurity, after controlling for income. Kontokosta, Reina, and Bonczak (2019) examined an extensive database describing 3,122 census block groups (CBGs) in five U.S. cities. Of these CBGs, 42% were classified as predominantly minority neighborhoods, and the remainder were predominantly non-hispanic white neighborhoods. For the three lowest income groups (≤50%, 51%–80%, and 81%–120% AMI), energy burdens in the two types of neighborhoods were statistically distinct. Very-low-income residents (≤50% AMI) in minority neighborhoods had energy burdens that were 1.56% higher than households of the same income category living in predominantly non-hispanic white communities. A similar difference was identified in the two other low-income groups (51%–80% AMI and 81%–120% AMI), although the gap in energy burden was smaller (Kontokosta, Reina, and Bonczak, 2019).

Energy burden also tends to be concentrated in rural areas, and states in the East South Central, New England and Mid-Atlantic regions have the highest rural energy burdens (Ross, Drehobl, and Stickles, 2018). Hoffman (2017) cautions against using aggregate national or regional indicators of energy burden, arguing that they can significantly underestimate the number of eligible households because the extremes in the distribution disappear when averages are examined.

2.2 CAUSES OF HIGH ENERGY BURDEN

The underlying causes of high energy burden identified in literature can be divided into five main categories – location and geography, housing characteristics, socio-economic situation, energy prices and policies, and behavioral factors (Table 2.1).

The first category of causes and correlates is geographic location, which is a strong predictor of energy burden. Low-income residents of rural communities and island territories pay higher-than-average bills for both electricity and heating fuels (Shoemaker, Gilleo, and Ferguson, 2018). With high energy costs, the benefits of energy efficiency could be significant, but rural residents face numerous other barriers such as a generally older housing stock that has produced a "rural energy-efficiency gap" (Winner et al., 2018).

Similarly, low-income households in the nation's largest cities face higher-than-average energy burdens (Drehobl and Ross, 2016). Fox (2016) and Brown[9] document the problem of low-income burdens in Southeastern states,[10] where poverty rates are high, and households consume significant amounts of energy for both heating and cooling to keep their aging and poorly built homes livable. There is a correlation between the types of fuels used for heating and cooling and their impacts on the household bills. HVAC systems in the South tend to be electric whereas heating in most other regions is dominated by natural gas, which is more affordable. In summer months and in hotter climates, households with electric space conditioning have greater opportunities to save energy (Bradshaw, Bou-Zeid, and Harris, 2016) whereas in the winter months, there is more potential to save energy in the colder regions (Bradshaw et al., 2014; 2016).

Finally, low-income neighborhoods can lack access to efficient appliances. For example, Reams, Reiner, and Stacey (2018) found that energy-efficient bulbs are less available in low-income areas, based on in-store surveys conducted in Wayne County, Michigan.

Second, housing characteristics are a major determinant of energy consumption and intensity (consumption per square foot). Older homes, public housing, and multifamily units also correlate with high energy intensity (Berkland, Pande, and Moezzi, 2018; Langevin, Gurian and Wen, 2013). Variation in maintenance and housing quality also manifests in the form of different levels of gas and electricity consumption (Scheu et al., 2018). Typically, low-income houses are older and undergo fewer repairs and upgrades over time. As a result, these housing units usually have inefficient insulation and older appliances, further adding to the energy burden (Cabeza et al., 2014). Bradshaw et al. (2014) also conclude that the overall savings potentials ultimately depend on the housing stock and the space conditioning equipment in use. In sum, much of the affordable housing/low-income housing in the U.S. remains energy inefficient despite advancements in building technologies and science.

Third, socio-economic characteristics determine a household's ability to afford energy-efficiency retrofits and more energy-efficient appliances (Thorve et al., 2018). Based on 2015 data from the Residential Energy Consumption Survey, low-income households use less energy than any other income group. However, they have the highest energy burdens, particularly households with incomes less than $20,000, whose energy burdens are more than twice as high as households who earn $20,000-$40,000.[11] While high-income households consume more energy, their EUI (that is, energy use per square foot of housing) is lower (Bednar et al., 2017).

[9] https://cepl.gatech.edu/sites/default/files/attachments/SCEN_PPT_Energy_Equity_05-30-18-Final_0.pdf
[10] https://www.energy.gov/sites/prod/files/2019/01/f58/WIP-Energy-Burden_final.pdf
[11] https://www.nclc.org/images/pdf/special_projects/climate_change/report-reversing-energy-system-inequity.pdf

Table 2.1. Causes and Correlates of High Energy Burden

Location and Geography	Housing Characteristics	Socio-economic Situation	Energy Prices and Policies	Behavioral Factors
• Rural, urban, Native American, remote community, island territory • Climate • Population density • Urban morphology (affecting access to jobs and efficient appliances)	• Thermal integrity of building • Type, age and size: single-family, manufactured, multifamily) • Owner-occupied vs rental and public housing • Age and type of appliances • Type of thermostat: WiFi, smart, programmable, touch screen	• Income • Ethnicity/Racial background • Immigrant vs native-born • Number of occupants, children, elderly, and handicapped	• Energy prices • Energy rate designs • Energy mix and access to natural gas • Availability and effectiveness of low-income energy programs and appliances	• Lack of knowledge • Misplaced incentives/ principal-agent problems (especially in multifamily homes) • Lifestyle cultural factors • Lack of control over energy bills • High non-monetary costs

Race and ethnicity also correlate with overall energy use, level of energy burden, and household energy consumption patterns. Hernandez et al (2016) and Bednar et al. (2017) find that African Americans have higher utility costs and higher Energy Use Intensity (EUI), as do Hispanic households. The underlying causes of these patterns are complex, but likely include impacts from historical housing injustices such as Jim Crow laws that enforced racial segregation. In addition, the size and composition of a household are key determinants of household energy consumption. Some of the same patterns are emerging in studies of other advanced energy technologies. For instance, Sunter et al. (2019) analyze rooftop solar adoption across the country and find that census tracts with larger shares of racial and ethnic minority groups have lower rates of adoption compared to white-majority census tracts.

Understanding the relationship between social demographics, load shapes and energy burden is only now emerging as a research focus (Jaske, 2016), which is particularly promising because it could help to guide efforts to manage consumption during the hours when it matters most.

The fourth category of causes and correlates of high energy burden is prices and policies. For example, high fixed components in power bills or reconnection fees are important barriers to reducing energy bills. These are discussed further in Section 3.

The fifth category covers behavioral determinants of energy consumption. Lack of knowledge and split incentives can be major hurdles to well-functioning housing markets, undermining investments in home retrofits and participation in energy efficiency programs. Building owners and managers know more about the energy performance and efficiency of their buildings than do prospective buyers and tenants, leading to the well documented situation of “lemons”, when consumers buy energy-inefficient appliances and homes because of imperfect marketplace information (Brown and Wang, 2015). Split incentives are especially evident in rental apartments where tenants do not have control over appliance choices and energy conservation measures, but they have to pay the bills (Brown, 2001). Tenants are often beholden to building owners and managers to make smart energy decisions based on their understanding of the energy integrity of the units. Tenants that are not provided information on behavior solutions or provided technical improvements, are likely to remain in situations of high energy use and burden (Berkland et al, 2018). In addition, residents of rental housing do not always have control over their energy bills; for example, building management may control the heating and cooling settings, resulting in thermal discomfort. This asymmetry of information and lack of control renders tenants vulnerable to high bills and the possibility of eviction.

Despite the stated willingness of most households to conserve energy and invest in energy-efficient appliances, there is often inconsistency between these values and their actual purchase behavior. These inconsistencies are sometimes based on various personal and contextual constraints including lack of available capital and nearby vendors (Brown and Sovacool, 2018).

Some energy programs have long waitlists of eligible program participants, while others face difficulty meeting their outreach and participation goals (Hirshfield and Iyer, 2012). From the utility's perspective, the small scale and dispersed nature of energy-efficiency projects challenges the aggregation of this resource, in-creasing its transaction costs. Effort is required to fill the "pipeline" with energy-efficiency projects that are investment-ready and creditworthy (Brown and Wang, 2015).

Such transaction costs suggest the case for utility partnerships with local community agencies that offer human services and already have people with completed income qualification paperwork for other programs (food, housing, medical care, etc.). This is particularly valuable for a program like WAP because its administrative costs are generally capped at 10%. (10 CFR 440). To take advantage of shared resources, WAP tends to be delivered alongside other social service programs so that transaction costs can be shared under the larger umbrella program (Community Action Agency). These types of transaction cost savings also motivated the MOU between DOE and HUD, which provided lists of income eligible "properties".

2.3 EFFECTS OF HIGH ENERGY BURDEN

High energy burdens have far-reaching and enduring consequences. Broadly defined, high energy burdens for low-income households have two types of inter-locking effects related to household economics and health.

Adverse economic and financial consequences often occur when low-income households with high utility bills have to make trade-offs between meeting alternative critical household expenditures. Paying for food, medical care, telecommunications, and shelter are often sacrificed in order to make timely utility bill payments (Hernandez et al., 2016; Camprubi et al., 2016). These trade-offs create a negative feedback loop that traps families in an enduring cycle of poverty. For example:

- Low-income families unable to pay their high energy bills become vulnerable to utility shut offs, which can lead to homelessness.

- Cash-strapped families and individuals become prey to predatory payday loans as their only option to pay utility bills and avoid shutoffs, which come with high interest rates that make repayment difficult[12] (Tonn et al., 2015).

Adverse health effects of high energy burdens can span a range of illnesses and conditions. These include exposure to carbon monoxide poisoning and other indoor air pollution due to the inefficient and improper use of unvented and subserviced wood stoves and propane heaters[13] (Fabian, Adamkiewicz, and Levy, 2012).[14] Other health effects noted in the literature are mental stress, lead exposure, thermal discomfort and respiratory problems such as asthma (Fabian et al., 2014; Wells et al., 2015; Chen, Xu, and Day, 2017). The fear of not being able to pay bills and the potential of losing electricity and home gas heating utility service altogether can stress mental health problems. There are also health effects related to inefficient energy usage and poorly insulated buildings. These effects are amplified for groups vulnerable to these conditions that often have limited adaptive capacity because of fewer resources (Hernandez et al., 2016; Massetti et al., 2017).

[12] https://cepl.gatech.edu/sites/default/files/attachments/SCEN_PPT_Energy_Equity_05-30-18-Final_0.pdf
[13] https://ktvl.com/news/local/wood-stove-and-heater-source-of-two-deaths-in-sisikyou-county
[14] Propane should be burned in an ideal ratio of 4 parts propane to 96 parts oxygen. Otherwise, it can lead to incomplete combustion of the fuel, which in turn releases carbon monoxide, a hazardous substance, especially when used in poorly ventilated areas. See: https://heattalk.com/propane-heat-pros-and-cons/

3. THE ECOSYSTEM OF LOW-INCOME ENERGY PROGRAMS AND POLICIES

Across the U.S., many programs and policies could help to address the energy burdens of low-income households.

3.1 TYPES OF PROGRAMS AND LEVELS OF EXPENDITURE

Finding: Many policies and programs that promote energy efficiency and renewable energy (e.g., rebates for Energy Star appliances and utility incentives for rooftop solar) are largely inaccessible to low-income households due to affordability barriers, although several states and coalitions of NGOs have recently launched major low-income solar programs and Energy Efficiency for All initiatives. Funding for temporary assistance (e.g., for bill payments) dwarfs funding for more enduring assistance (e.g., weatherization) (Hoffman et al., 2018; Cluett, Amann, and Ou, 2016), though both serve a critical need and benefit from being linked together. Funding for low-income energy programs peaked as a result of the American Recovery and Reinvestment Act (ARRA); it has returned to levels above the pre-ARRA funding, reflecting modest increases in weatherization funding and more substantial increases in low-income solar programs (O'Dwyer, 2017).

Since the mid-1970s, numerous programs and policies have been implemented in the U.S. to promote residential energy efficiency and reduce household energy bills (Berg et al., 2018; Brown and Wang, 2015). For example, state building codes have improved the energy integrity of new home construction, and appliance standards have raised the energy performance of household equipment, arguably becoming the largest contributor to the energy efficiency of low-income housing today. In addition, financial incentives in the form of income tax credits and tax-free loans are available for taxpaying households to make investments in energy efficiency and renewable energy projects. However, participation from low-income households remains low (Zhao et al., 2012). In contrast, weak energy-efficiency regulations can also disadvantage low-income households. For example, while few low-income households live in new homes, the fact that poor building codes cause homes to be built without a focus on energy creates a missed opportunity with an impact that can last a century and ultimately challenge the affordability of low-income households. Energy Star ratings have helped educate consumers about the energy consequences of the products they purchase, and federal tax policies have subsidized home energy retrofits. Several states also offer low-income homeowners financial incentives to overcome the high up-front cost of energy-efficiency appliances and equipment.[15] However, participating in these programs (purchasing new appliances and retrofitting homes) is not affordable for many low-income households.

More recently, policies and programs have been launched to accelerate the deployment of energy efficiency and renewable energy. These include more than a decade of federal investment tax incentives and utility net metering programs that support rooftop solar panels and home battery storage systems. The federal government provides tax rebates to subsidize the purchase of electric vehicles, and many states are implementing programs to pay for the development of vehicle charging infrastructure (Narassimhan and Johnson, 2018). We do not review this

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[15] Database of State Incentives for Renewables & Efficiency (DSIRE) Financial Incentives for Energy Efficiency (2012). https://programs.dsireusa.org/system/program/tables

complex ecosystem of policies because low-income households generally cannot afford to purchase new electric vehicles even with the rebates that are offered.

However, questions are being asked about the fairness of incentives that promote a transition to energy efficiency and renewable energy technologies when they are largely inaccessible to low-income households. For example, Cluett et al. (2016) note that a majority of utility energy-efficiency programs require an up-front customer investment to leverage rebates and associated savings, which makes them unaffordable to low-income households. Low-income households often cannot afford the up-front financial “match” required to obtain the rebates and loans available to consumers who buy energy-efficient household appliances. As a final example, the federal government promotes residential energy-efficiency and solar systems investments by offering tax credits. In the case of rooftop solar systems, these are called Investment Tax Credits. Such federal tax credits are worth very little to most low-income homeowners because they typically have limited tax liability.

This inequity is compounded by the fact that energy-efficiency programs raise electric and other utility costs by increasing the share of fixed utility fees for all customers (Johnson et al., 2017; Sigrin and Mooney, 2018). While such inequitable impacts of electricity and natural gas tariffs can be offset by modest low-income energy assistance programs (Borenstein and Davis, 2012), such offsets are rarely established.

Within the U.S. policy ecosystem, numerous and diverse energy programs and policies do target low-income households. Table 3.1 summarizes these in a matrix organized by implementing organization and type of program. Program implementers range from electric and gas utilities and federal and state agencies, to local government and community-based entities and philanthropic and nonprofit organizations. Program types distinguish between utility bill assistance, financial incentives, energy information, and regulations. Initiatives (such as the Clean Energy for Low Income Communities Accelerator or CELICA) have also facilitated cross-organizational coordination in this space. The CELICA program helped lower energy bills for households by facilitating a partnership between the DOE and sub-national governments (DOE, 2017). Gilleo, Nowak, and Drehobl (2017) identify some core practices of successful low-income energy efficiency programs. Some of these include ensuring statewide coordination, targeting program offerings to sections that yield the highest benefits, forming partnerships with local outreach organizations, and providing a single point of contact to participants and contractors.

Table 3.1 Illustrative low-income energy policies and programs

	Energy Bill Assistance	Financial Incentives	Energy Information	Regulations
Electric and Gas Utilities	• Bill forgiveness programs • Budget billing • Prepaid electricity services • Payment plans	• Direct installation of efficiency measures • Round-up assistance programs • On-bill program designs	• Goal setting for low-income programs • Installation of home energy management systems • Real-time appliance and premise level feedback	• Rates and rate design • Shut-off and reconnection policies • Integrated resource planning • Adders for cost-effectiveness tests • Minimum requirements for low-income programs
Federal Agencies	• Low Income Home Energy Assistance Program (LIHEAP) • HUD assisted housing utility allowance subsidies • USDA housing utility allowance subsidies	• Weatherization Assistance Program (WAP) • LIHEAP weatherization • Energy Efficiency and Conservation Loan Program (EECLP) • Low-Income Housing Tax Credit (LIHTC) program • HUD HOME/CDBG home repair funding	• WAP includes education of clients as an allowable activity • WAP Technical Assistance and Training • HUD Utility Benchmarking guidance	• Subsidized housing regulations • Federal Housing Administration (FHA) Duty to Serve • Environmental Protection Agency (EPA) energy justice and climate regulations • Federal Energy Regulatory Commission (FERC) affordable power for all regulations
State Agencies	• Implementation of federal bill assistance programs • State administered ratepayer funding for bill assistance	• Implementation of federal low-income energy efficiency programs including support for local, state and regional initiatives • State and county funds supplement WAP	• Technical assistance • Tools • Case studies • Peer exchange • Goal setting • Convening • Stakeholder engagement	• Subsidized housing regulations • Minimum requirements for low-income utility programs
Local Government, Community-Based Entities, and NGOs	• Bill forgiveness programs	• Weatherize Campaigns • Home repair financing	• Healthy housing programs • CDC Lead Control • Building codes and ordinances • Community education, outreach • Community convening • Pilot projects	• Subsidized housing regulations • Building and energy codes and standards

Based on data principally from 2013 (see the notes for Figure 3.1), approximately 80% (or about $6.3 billion) of low-income energy funding goes to bill payment assistance, 14% ($1.17 billion) to energy efficiency, and 5% ($38 million) to unspecified support (Cluett et al., 2016, p. 7). Altogether, utilities are the single largest source of funding for low-income energy programs. Ratepayer-funded utility programs provide 41% of the total funding for low-income bill assistance and 10% of the total funding for low-income energy-efficiency programs. Thus, Public Service Commissions, Boards of Directors of public utilities, and other state regulators are critical to establishing the policy ecosystem within which utilities design and implement low-income energy programs. Federal agencies provide 44% of the total (40% from LIHEAP for bill assistance, 2% from LIHEAP for efficiency, and 2% from DOE for the Weatherization Assistance Program). In 2016, the block grant allocation to LIHEAP was $3.3 billion, reallotment funds were $1.2 million, and funds carried over from previous year was $167 million.[16] State and local contributions at 3% and nonprofit organizations at 2% complete the picture. These funds are used for heating and cooling assistance, crisis assistance, administrative and planning needs and any other requirements at the state level. These sources are somewhat dated and cross-cut different years, as would be expected from a review of the literature, which is distinct from a review of information in databases.[17]

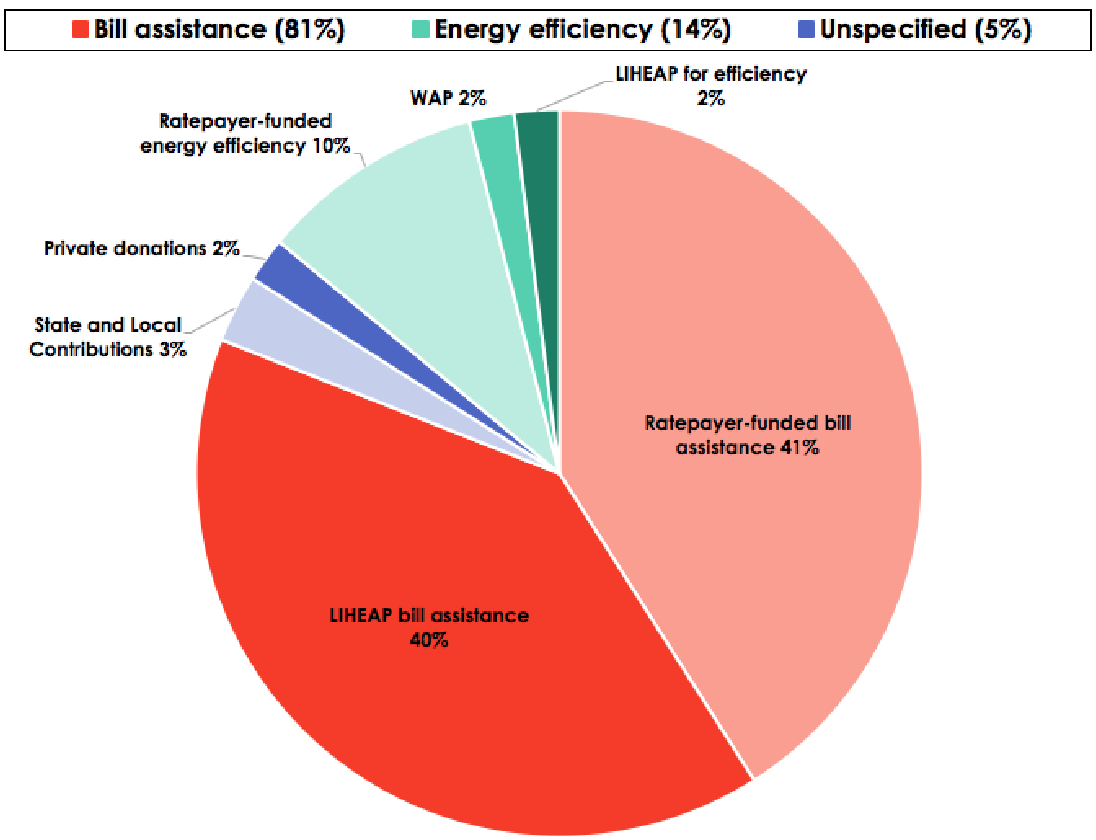

Figure 3.1 Expenditures on low-income energy programs
(Redrawn from Cluett et al., 2016, Figure 2)

(Notes: Funding for most of the categories are based on data for 2013; LIHEAP spending on efficiency is based on 6% of LIHEAP funds spent on efficiency in 2006. Data on state and local contributions and private donations are estimated for 2010, based on LIHEAP Clearinghouse 2016. Excludes solar programs and some affordable housing energy incentives, e.g., tax credit financing.)

[16] https://liheappm.acf.hhs.gov
[17] More updated sources for WAP and LIHEAP (including LIHEAP Wx funding) can be found at https://nascsp.org/wap/weatherization-publications/wap-annual-funding-surveys/

Over the past decade, annual expenditures on low-income energy-efficiency programs have ranged widely between about $1-$3 billion/year. The greatest source of variability is the funding for DOE's WAP. The American Recovery and Reinvestment Act (ARRA) of 2009 raised WAP's appropriations from historic levels of $150 to $230 million each year since its inception in the late 1970s, to $5 billion between 2009 and 2011. As a result, WAP in 2010 spent an unprecedented $2 billion, implemented by nearly 60 Grantees and about 1,000 Subgrantees. With leveraging, the national weatherization network expenditures rose to $2.7 billion in program year 2010 (Tonn, et al., 2015, p. xvi).[18] In the post-ARRA period, WAP has been operating at approximately the pre-ARRA Congressional appropriation level, peaking in 2019 at $254 million.[19]

In addition to these funds, some states and counties use General Assistance, emergency assistance, local tax revenues, or similar funds to supplement federal LIHEAP funding. These funds may help low-income families pay for fuel, utilities, furnace repair, or other charges; some also help households avoid utility shut offs during summer/winter. Eligibility criteria vary by state; for example, some states require that applicants must be in an emergency condition.[20]

Corporate and private funds also support fuel assistance for low-income households. Eligibility is variable, but typically requires an emergency situation. Program administrators are typically state social services agencies. One of the largest funds is managed by the Citizens Energy Corporation, which uses proceeds from natural gas sales to provide charitable emergency assistance to 25 states.[21]

3.2 ELECTRIC AND GAS UTILITY PROGRAMS AND POLICIES

Finding: The share of utility residential energy-efficiency funding that supports low-income households is lower than the percent of residential utility customers who are low-income (Drehobl and Castro-Alvarez, 2017).

Public utility commissions and city councils set customer benefit surcharges that are collected through customer utility bills. Utilities then use this money to fund low-income energy-efficiency programs. In 2014, energy efficiency spending for low-income programs accounted for 18% of residential electric efficiency spending and 34% of residential natural gas efficiency spending. The target segment of the population accounts for roughly one-third of total households, although this depends on how low-income status is defined.

Low-income households are not excluded from programs offered to all residential customers, but data show that they are less likely than other customers to participate in them.[22] Non-low-income utility energy-efficiency programs, for example, often target homeowners and not renters, and they typically require participants to pay for a portion of the weatherization costs, which can be prohibitive for low-income households who tend to rent their homes and have limited

[18] To spend the additional funding, income eligibility requirements were extended to 200% of the federal poverty level (rather than 150%), and the maximum WAP investment allowed per home was raised from $2500 to $6500. As a result, participating households had higher incomes and fewer vulnerable household members (Tonn, Rose, and Hawkins, 2015).
[19] https://nascsp.org/wp-content/uploads/2018/02/fy201720wip20fact20sheet.pdf; https://www.edf.org/energy/equity-through-energy-efficiency
[20] http://neada.org/state-tribal-programs/state-energy-assistance-directors/
[21] https://www.ncoa.org/wp-content/uploads/Alternative-Sources-of-Energy-Assistance.pdf
[22] https://beccconference.org/wp-content/uploads/2015/10/presentation_frank.pdf

discretionary income. Because of their limited means, low-income households are also least able to participate in many types of initiatives aimed at reducing energy costs. At the state level, resources are typically insufficient to deliver energy efficiency and renewable energy services for all low-income households. A study of such policies in New York State concluded that markets are not always able to meet the public policy objectives (CEAC, 2017). The study recommends that to address the needs of the state, the utilities and the regulatory commission should follow a holistic approach such that the often-insufficient budgets are used towards cross-cutting initiatives to reach the largest portion of the state's population.

Relf, Baatz, and Nowak (2017) estimate that on average, utilities enabled (through financing and assistance) 5.29 kWh of low-income energy savings per residential customer and spent 8.93% of total energy-efficiency program funds (including residential, commercial, and industrial programs) on low-income programs in 2016. However, the low medians for both of these statistics (2.80 kWh/residential customer and 6.23% of total spending), indicate that the top performers are boosting the group average. For example, 22 utilities offer comprehensive programs including more than one low-income program as well as natural gas programs.

A similar pattern of spending and accomplishment was reported in a survey of the nation's 51 largest metropolitan statistical areas. In 2015, 49 metropolitan statistical areas (MSAs) were served by a low-income electricity efficiency program, and 31 were served by a low-income natural gas efficiency program. But the amount spent and savings achieved are highly variable across programs and fuels (See Table 3.2).

Table 3.2 Summary of Amount Spent and Savings Achieved Across Programs and Fuels, in 2015

(Source of data: Drehobl and Castro-Alvarez, 2017).

Electric energy efficiency programs		
Spending	Average spending on electric efficiency programs per low-income participant was $1,538	Per low-income customer, these averages drop to $3.
Savings	Producing 1,377 kWh of savings.	Producing 22 kWh of savings.
Natural gas programs		
Spending	Average spending on electric efficiency programs per low-income participant was $2,002	Per low-income customer, these averages drop to $23.
Savings	Producing 135 therms of savings	Producing 3 therms of savings.

The cities with the largest expenditures per low-income customer were Boston, San Antonio, Providence, San Francisco, and Hartford. In terms of kWh of electricity savings per low-income customer, the most impactful cities were Boston, Hartford, San Antonio, Providence, and Louisville, which each saved >50 kWh per low-income customer (Figure 3.2). About half of the electric and natural gas programs coordinated with WAP in 2015, indicating significant potential for improved leveraging. Many, but not all programs target specific households such as high energy users, which also indicates room for improvement. State WAP grantees specify priority populations in their annual state plans, targeting elderly, disabled, families with children, and high energy users in accordance with the WAP statute. What this map does not show is how much is spent per customer. Some areas have a lot more to spend or may decide to spread resources more broadly on low-income households.

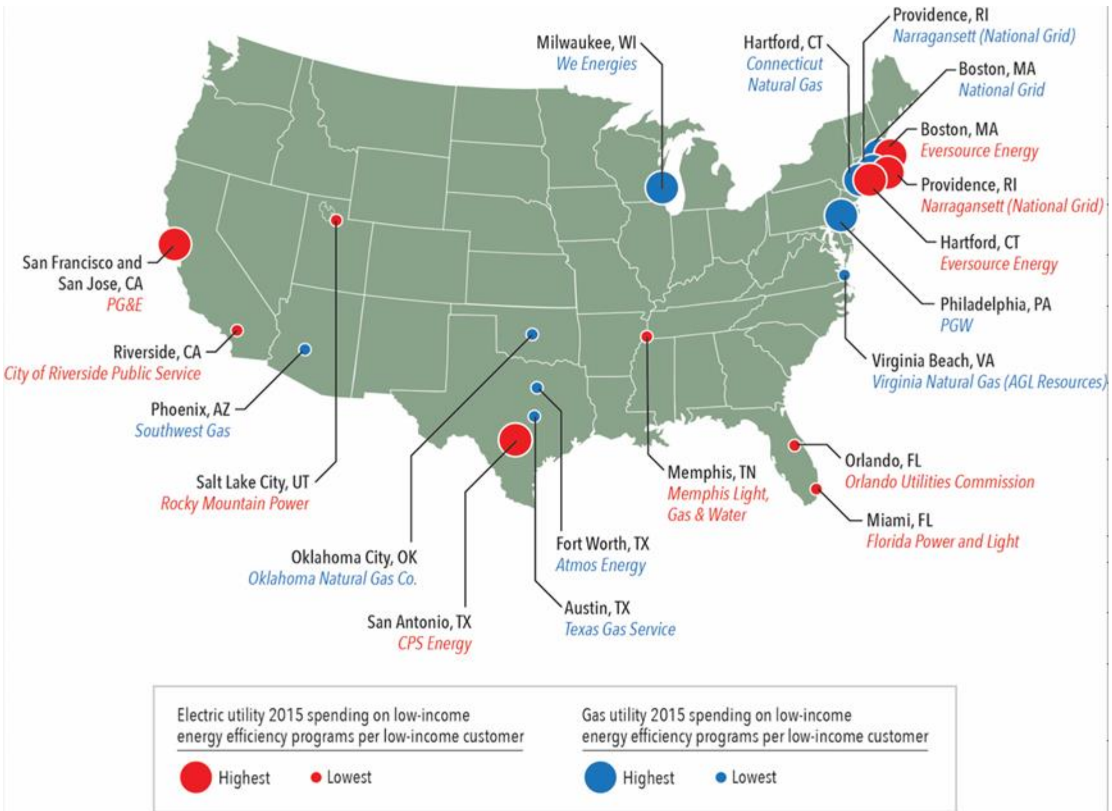

Figure 3.2. Electric and gas utility spending on low-income energy-efficiency programs per low-income customer in 2015.

(Source: Authors, based on data from Drehobl and Castro-Alvarez, 2017)

Across rural America, utility expenditures on energy-efficiency programs are lagging behind. Evidence from 12 utilities offering tariffed on-bill financing (Hummel and Lachman, 2018), and detailed analysis of on-bill programs implemented by a rural electric co-op in Arkansas suggests that the Pay-as-You-Save approach offers an effective approach. Household energy usage was decreased by almost a quarter, and the utility benefited from peak demand reduction, as well (Lin, 2018a). These results suggest a promising approach for the more than 900 cooperatives in the country. (See Section 3.2.2 below.)

Utility companies offer an array of programs and policies to help customers who are in arrears and to recover costs associated with non-payment. Utilities can implement prepaid electric service (see Section 3.2.4 below), offer payment plans (see Section 3.2.5 below), and implement alternatives to shutting off services. They can also eliminate late fees and interest and can promote level billing to reduce spikes in prices during extreme weather events. However, there is also evidence of the potential negative impact of some of these programs leading to “selfdisconnection", propagating inequities, and adding stress to the households under difficult financial situations.[23]

Utility companies and their customers can both benefit from such activities by reducing costs associated with shut-offs and reconnections (Hernandez and Bird, 2010). While these services and procedures are not intended to be long-term solutions to the low-income energy burden problem (Verclas and Hsieh, 2018), they can be effective in the short-run until the housing stock, HVAC equipment, and appliances can be made more energy efficient.

3.2.1 Integrated Resource Planning, Goal Setting, and Cost-Effectiveness Tests

Many utilities have a history of using ratepayer resources to support low-income energy programs. In regulated markets, these programs are often proposed in integrated resource plans (IRPs) that are typically written every three years or so by utilities and reviewed by Public Utility Commissions or other regulatory entities. Goals may be set by these Commissions, and cost-effectiveness tests are often deployed to determine if subsequent investments are cost-justified. Regulators of public utilities, such as the Board of Directors of the Tennessee Valley Authority (TVA) can authorize budgets for such expenditures. This was the case with the "Extreme Energy Makeover Program" low-income program launched in 2015, which was approved by the TVA Board as a response to EPA regulations and fines. The program targeted around 800 old homes (20 years+) located in lower-income communities and it had an electric energy usage reduction target of 25% per home.[24]

Local power companies can also initiate program and project proposals, which are then reviewed by Utility Commissions and may be discussed in public hearings independent of IRPs. Typically, Utility Commissions specify in advance the cost-effectiveness tests that will be used to evaluate such proposals. Different tests dominate different regions of the U.S. For instance, the Rate Impact Measure (or "nonparticipant test") is relied upon in the Southeast, while California and the Pacific Northwest emphasize the Total Resource Cost test and the Societal test that allows for the inclusion of the cost of environmental externalities. The more that societal impacts are considered (such as environmental and public health benefits), the higher the benefit-cost ratio of low-income energy-efficiency expenditures.

3.2.2 Residential On-Bill Program Designs

A residential on-bill program is a type of financing design that can be explicitly used to incentivize energy-efficiency projects by low-income utility customers. It is a financial product that is serviced by a utility company for energy-efficiency improvements in a building and is repaid by owners on their monthly utility bills. Such tariff designs can help overcome liquidity and budget constraints of low-income households. The utility pays the up-front cost of a project, and customers repay the utility as savings accrue each month. Following best practices, only those energy efficiency measures that are estimated to provide net bill savings are installed. Tying repayment of energy-efficiency investments to utility bills allows households to consider energy upgrades as an operational savings rather than a capital expenditure (Gillingham, Newell, and Palmer, 2009). While these programs require the participation of a utility, they also often

[23] https://www.nclc.org/issues/prepaid-utility-service.html
[24] https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/Air%20Quality/EPA%20Mitigation%20Projects/Smart%20Communities%20-%20Extreme%20Energy%20Makeovers%20FAQ.pdf

benefit from government support in terms of legal authority and the initial financing, as is the case with the Energy Efficiency and Conservation Loan Program (EECLP). ESPCs and ESAs also address the problem of up-front financing.[25]

On-bill financing opportunities through utilities are expanding with minimal defaults: more than a dozen states have on-bill financing programs, and other states have pilot programs or are in the process of creating programs (Hummel and Lachman, 2018; Bell, Nadel, and Hayes, 2011; Leventis et al., 2016). The financing model would appear to be promising for owner-occupied housing, but it may not be a good fit for building owners (who take on the liability for the debt) with tenants (who typically have responsibility for the energy bills) (Brown and Wang, 2015). This is called the split-incentive challenge.

Pay-as-you-Save (PAYS) financing is an example of a tariffed on-bill financing program. It is modeled to provide 20% savings to the customer, with 80% going to repayment of cost of project. Lin (2018a) highlights the PAYS potential for success in a case study highlighting a rural Arkansas co-op. The program produced electricity bill savings to customers and benefits to implementing utilities, especially in rural areas. Through its on-bill tariff design, PAYS overcomes many barriers, such as the split-incentive challenge and the need for upfront outlays. Hummel and Lachman (2018) summarize field data reported by 12 utilities offering inclusive financing through tariffed on-bill programs in six states. Cost recovery rates in these programs have exceeded 99.9%, and no utility has reported a case of disconnection for nonpayment of PAYS charges. Their program data produces a striking picture of an inclusive financing mechanism that can reach previously underserved markets even in areas of persistent poverty.

Despite these various benefits, it is important to note that any type of property lien can have negative consequences. For example, Atlanta, Georgia, households with liens on properties were deemed ineligible for accessing a tax relief fund for legacy residents.[26]

3.2.3 Round-Up Assistance Programs

Round-up assistance programs are designed to provide financial assistance to families and communities in need of help. It is a voluntary program in which utility customers agree to have their utility bill "rounded up" to the next whole dollar amount. The extra money paid on a utility bill, which is a donation to the round-up program fund, goes towards helping the less fortunate pay their bills and other community-based programs.[27] The utility designs the program such that the customer can either opt in, or opt out (i.e., customers are automatically enrolled in the program and must "opt out" in order stop contributing to the round-up assistance fund. Utility round-up programs are particularly prevalent amongst municipal and local cooperative utilities. States, however, are now introducing policies that require utilities to pro-actively inform their customers about the round-up programs if they operate on an "opt-out basis".[28]

The round-up funds raised from customers, often supplemented by donations from utility companies and local businesses, are put into a fund used to assist local individuals and community organizations with crucial needs. Many of those who receive financial help are low-

[25] https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-financing-low-and-moderate-income-households-current-state-market
[26] Source: Erin Rose, Three Cubed, personal communication, August 2019.
[27] https://www.needhelppayingbills.com/html/operation_round_up_assistance_.html
[28] https://legiscan.com/TN/text/SB0308/2019

income families with children, seniors, and someone just facing a short-term crisis. In some cases, the charity run program also provides cash grants to community projects and local nonprofit organizations such as food pantries, volunteer fire departments, and rural ambulance services. In addition, assistance is also provided directly to individuals. Round-up programs may help with utility bills, rent, food, shelter, health care, clothing, emergency services, education, job training, and other charitable causes.

For example, under Northwest Georgia Electric Membership Cooperative's (NGEMC) Round-up Program, a monthly bill of $70.01 is rounded up to $71, with 99 cents going to the program that makes donations to community nonprofit organizations in the seven counties the cooperative serves.[29] All of NGEMC's 98,000 customers were enrolled in the program automatically at the outset of the program, and the program has awarded annual grants to individuals, families and communities in need totalling more than $100,000 each year since 2016.

3.2.4 Prepaid Electric Services

Prepaid services are emerging in many product areas, including prepaid gift cards, transit cards, pay-as-you-go cell phones, and pre-loaded credit cards. They allow customers to manage and budget their expenditures in advance. Many countries around the world have implemented prepaid electric services, and utilities in the U.S. are beginning to implement them, particularly municipal and co-op electric service providers. In this context, prepaid services give the customer more oversight and control over usage, but the short-term credit inherent in the post-paid model is lost (Chen, 2012).

Because prepaid electricity services do not require a deposit, they can be appealing to low-income customers. With the availability of digital meters with remote connection and disconnection capabilities, utilities can respond quickly to a customer's account status, reducing the time required to turn service on and off, thereby reducing disconnection times, and with advance alerts from the utility, the customer can quickly replenish the account and avoid service shut-off.

At the same time, with increased smart meter deployment, there is a potential for increased disconnections. Prior to smart meters, each disconnection required a costly physical trip to the meter. Smart meter technologies allow utilities to disconnect customers remotely (Verclas and Hsieh, 2018).

It has been argued that prepaid service generally costs the distribution utility less than postpaid service because it reduces the utility's carrying costs, uncollectible accounts, and collection costs (Chen, 2012). Reflecting this fact, the National Association of State Utility Consumer Advocates (NASUCA) passed a resolution advising utilities that "Rates for prepaid service are lower than rates for comparable credit-based service,..."[30] Data on the adoption of prepaid service and its impact on rates and disconnection times are difficult to obtain.

[29] https://www.ngemc.com/ORU
[30] http://nasuca.org/nwp/wp-content/uploads/2014/01/NASUCA-2011-3.pdf

3.2.5 Payment Plans

Payment plans allow customers in arrears to pay off their debt over time. State regulations typically require utilities to offer payment plans to customers who are in arrears and at risk of disconnection (Chen, 2012). Customers must repay their arrearage over a predetermined number of months, provide a down payment, and pay a minimum towards their electricity bill. Such payment plans often are based on the amount that the customer owes and do not consider the ability of the household to pay. As a result, the customer debt levels can continue to increase (Verclas and Hsieh, 2018).

In addition, there is evidence that budget billing (BB) and level billing can increase consumption. Both types of billing dilute the price signal because customers do not see seasonal or monthly variations in cost (Treadway, 2018). Getachew et al.[31] estimates that budget billing increases energy consumption by 3.8% to 4.7%, on average. Sexton (2015) found that automatic bill payments (ABP) and budget billing used by PG&E customers can cause an increase in customers' energy consumption, attributable to a loss of price salience. For low-income customers, this would mean even larger utility bills for consumers who are already struggling with high energy burdens. DNV GL provide evidence that PG&E's Home Energy Report (HER) Program at least partially claws back these increases, which suggests that ABP and BB should be coupled with HERs to combat the loss of price salience.[32]

3.2.6 Disconnection Alternatives

Utility companies and their customers can benefit by reducing costs associated with shut-offs and reconnections (Hernandez and Bird, 2010). While these services and procedures are not intended to be long-term solutions to the low-income energy burden problem (Verclas and Hsieh, 2018), they can be effective in the short-run while the housing stock, HVAC equipment, and appliances are made more energy efficient.

Lack of data on the frequency and duration of utility shut-offs makes it difficult to quantify the explicit and implicit costs associated with utility disconnections. Electricity termination can have health and safety consequences, which can be particularly serious for the elderly and young children, and for those needing medical equipment. It can also cause social stigma and ultimately lead to homelessness because many landlords consider disconnection to be grounds for eviction. While some states collect data on utility shut-off and disconnection, for privacy reasons, the data usually only includes the number of accounts disconnected, without indicating whether a limited number of accounts are being disconnected multiple times or if a large number of accounts are getting disconnected and reconnected just once (Verclas and Hsieh, 2018).

The EcoPinion Consumer Survey No. 23 conducted in 2015 (Wimberly, 2016; 2017) provides some assessment of the extent of the problem. Four percent of households with incomes less than $50,000 had their electric service disconnected within the previous two years. This rate increased to 6% for renters and doubled to 8% for households earning less than $25,000. With 24.4 million

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[31] . https://beccconference.org/wp-content/uploads/2017/10/sadhasivan_presentation.pdf

[32] http://calmac.org/results.asp?flag=&searchtext=Auto+Pay&pubsearch=1&selAuthor=252&dFrom=1%2F18%2F1990&dTo=12%2F28%2F2018&yFrom=1980&yTo=2018&selPubDates=1%2F1%2F2003&selToDate=12%2F28-2018&selProgYear=&selToYear=&pubsort=1&Submit=Search

households earning less than $25,000,[33] this suggests that nearly 2 million U.S. households have had their electricity disconnected over the past two years.

Most utilities have disconnection policies that make households vulnerable to energy insecurity. To temper the effects of disconnections, most states have policies that protect households by setting procedures consistent with the 1978 case of Memphis Light, Gas and Water v. Craft (436 U.S. 1, 1978).[34] The U.S. Supreme Court ruling recognized that "The customer's interest in not having services terminated is self-evident, the risk of erroneous deprivation of services is not insubstantial, and the utility's interests are not incompatible with affording the notice and procedure described above."[35] The U.S. Supreme Court has also ruled that all customers have a constitutional right to be given notice prior to termination of utility service.[36] Though a minimum level of notice is required, the length of notice and notice procedures vary widely across states. Robust notice policies could protect customers from being disconnected and alert them of their duty to pay for utility service, but delivery is complicated by factors such as language barriers and an inability to reach customers when phone and internet access are unavailable, which is often the case in low-income households.

States typically provide one or more types of disconnection limitations (Verclas and Hsieh, 2018). They range from being date based (to cover winter months), temperature-based, or tied to the need for medical equipment such as nebulizers, life support machines, and dialysis machines.

These procedural protections are not long-term solutions to the low-income energy burden problem. They do not provide financial support or other assistance to provide low-income customers with a chance to overcome debt to the utility in the long term. Additional policies are needed to help customers maintain energy access.

3.3 FEDERAL PROGRAMS AND POLICIES

Finding: At least four federal programs have missions related to low-income energy burdens, with varying levels of inter-agency coordination.

The dominant low-income federal programs and policies are the Weatherization Assistance Program (WAP) operated by the DOE and the Low Income Home Energy Assistance Program (LIHEAP) operated by the U.S. Department of Health and Human Services (HHS). In addition, EECLP, managed by the Rural Utilities Service for the U.S. Department of Agriculture (USDA), and the Low-Income Housing Tax Credit (LIHTC) Program run by the U.S. Housing and Urban Development (HUD) and supported by the US Treasury are also described because of their pertinence to low-income households.

3.3.1 DOE Weatherization Assistance

DOE's Weatherization Assistance Program was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of this Program is to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-

[33] https://www.statista.com/statistics/203183/percentage-distribution-of-household-income-in-the-us/
[34] https://supreme.justia.com/cases/federal/us/436/1/
[35] Mathews v. Eldridge, 424 U. S. 319. Pp. 436 U. S. 16-19.
[36] https://supreme.justia.com/cases/federal/us/436/1/

income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with a high energy burden (see 10 CFR 440.1 and the discussion of it in Carroll, Kim, and Driscoll, 2014). The program treats single family and mobile homes, and multifamily buildings in all climate zones.

WAP provides grants to U.S. states, territories, and tribes, which then provide grants to local weatherization agencies to weatherize income-eligible low-income homes. These Grantees demarcate their own eligibility criteria, subject to WAP restrictions. The federally stipulated guideline is 200% of the Federal Poverty Level (FPL) or 60% State Median Income. LIHEAP uses a lower income threshold (150% FPL), and utility low-income programs tend to match WAP or LIHEAP, although they may qualify households up to 80% AMI and may also have moderate-income programs.

Households that receive Supplemental Security Income or Temporary Assistance for Needy Families (previously called Aid to Families with Dependent Children) are automatically eligible to receive weatherization services. Per WAP guidance, states give preference to:

- People over 60 years of age
- Families with one or more members with a disability
- Families with children
- Those with a high energy burden
- Those with high energy usage

As noted earlier, bill assistance provides a critical service to low-income households in crisis situations. Weatherization reduces energy usage and thereby decreases energy costs over the long term. Weatherization provides a longer-term solution to energy burden by addressing insulation, air infiltration, baseload energy use, and energy-efficient appliances to make homes more energy efficient. Since 1979 through the Weatherization Assistance Program and other leveraged funding, DOE has funded or otherwise supported energy-efficiency improvements and minor associated repairs for more than 7 million low-income households (Hoffman, 2017).

"Professionally trained weatherization crews use computerized energy assessments and advanced diagnostic equipment, such as blower doors, flue-gas analyzers, and infrared cameras to create a comprehensive analysis of the home to determine the most cost-effective measures appropriate and to identify any health and safety concerns associated with the energy retrofits. Weatherization providers also thoroughly inspect households served to ensure the occupant's safety, check for indoor air quality, combustion safety, and carbon monoxide, and identify mold infestations – which are all indications of energy waste. The auditor creates a customized work order, and trained crews install the identified energy efficient and health and safety measures."[37] 100% of units served under WAP receive an inspection from a certified Quality Control Inspector who ensures all work is completed correctly and that the home is safe for the occupants. Additionally, State WAP Grantees inspect 5-10% of these units, providing an additional layer of quality assurance.

[37] https://nascsp.org/wp-content/uploads/2017/09/WAP_ProgramOverviewFactSheet_3.16.17.pdf

In 2015, utilities and states supplemented DOE funding by providing an additional $883 million, or $4.62 for every dollar invested by DOE.[38] This estimate includes utility funds, and any state or local funds that were coordinated with DOE's WAP. The National Association of State Community Services Programs (NASCSP) tracks the leveraging of each state; more information on state LIHEAP transfers can be found in the HHS LIHEAP Clearinghouse Database.[39]

3.3.2 LIHEAP Bill Assistance

LIHEAP bill assistance directly compensates some of the cost of energy burden for qualifying households. It is the primary source of bill assistance to low-income high-energy burden areas. LIHEAP began in response to the increasing price of utility bills in the 70s, and the inability of low-income families to safely live in their homes because they could not afford to pay these bills. It is funded by the federal government, where funding for the program is dependent on the federal budget. HHS and the Office of Community Service within the Administration for Children and Families are the governing agencies over LIHEAP. Grantees must submit annual reports to HHS in order to participate in LIHEAP programs. They are given a block grant to help low-income families. Usually the parameters on how these households are assisted are very broad, but most of the funds are used for two-party checks between the bill payer and the utility company.

The assistance is meant to cover those with the lowest of incomes and relatively highest energy bills. According to the National Energy Assistance Director's Association (NEADA), in 2015, LIHEAP provided essential heating assistance to 6.9 million households, and essential cooling assistance to about 996,000 households. In 2009, LIHEAP was budgeted $5.1 billion, which was the most it has been in history. LIHEAP's recent annual budgets of about $3 billion is only able to serve about 20% of the eligible households in the country (Drehobl and Ross, 2016). The most common reason for not applying for bill assistance is a lack of awareness of assistance programs and confusion over how to apply (Treadway, 2018).

Weatherization funding is also available from LIHEAP. Up to 25% of LIHEAP appropriations can be spent on weatherization at the discretion of the authorizing state agency. The LIHEAP Statute[40] requires that grantees receive a state waiver to increase the maximum from 15% to 25%.[41] NASCSP tracks the leveraging of each state.[42] Its most recent funding report estimates that in FY 2017, the $223.5 million of DOE WAP funding leveraged $423.1 million of LIHEAP funding and $225.6 million of other funding, mostly from utilities ($138.3 million).[43]

HHS requires grantees to have a plan on how to use LIHEAP funds for weatherization and the funds must be expended in accordance to the plan. Grantees can choose to administer the LIHEAP funds according to: entirely DOE WAP rules, entirely LIHEAP rules, mostly LIHEAP rules, or mostly DOE rules.[44] LIHEAP weatherization investments must be for cost-effective,

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38 https://nascsp.org/wp-content/uploads/2017/09/WAP_ProgramOverviewFactSheet_3.16.17.pdf
39 https://liheappm.acf.hhs.gov/data_warehouse/index.php?report=homepage
40 https://liheapch.acf.hhs.gov/pubs/liheapstatute.htm
41 https://liheapch.acf.hhs.gov/delivery/components.htm
42 https://nascsp.org/wp-content/uploads/2019/02/NASCSP-2017-WAP-Funding-Survey_FINAL_2.9.-2019.pdf
43 https://nascsp.org/wp-content/uploads/2019/02/NASCSP-2017-WAP-Funding-Survey_FINAL_2.9.-2019.pdf See Tables 1 and 8
44 https://neuac.org/wp-content/uploads/2018/07/1B-Burrin.pdf

residential weatherization measures or other energy-related home repairs that do not constitute construction.

In about half of the U.S. states, WAP and LIHEAP are located in the same office. The LIHEAP/WAP relationship is valuable. For example, tracking WAP deferrals can be used to effectively target LIHEAP funds and LIHEAP recipients with high energy burden can be directly referred to WAP for services.[45]

3.3.3 Other Federal Programs and Policies

At least two additional federal initiatives have a strong direct impact on the energy burden of low-income households: The Energy Efficiency and Conservation Loan Program (EECLP) operated by the USDA and the LIHTC tax credit monitored by the Internal Revenue Service (IRS). EECLP provides loans to finance energy efficiency and conservation programs of rural electric cooperatives that serve towns or unincorporated areas with no more than 20,000 inhabitants.[46] Eligible utilities can borrow money tied to Treasury rates of interest and re-lend the money to develop new and diverse energy service products within their service territories. The borrowed funding must be used to improve energy efficiency or encourage the use of renewable energy fuels for demand-side management, including solar PV systems, energy audits, community awareness and outreach, as well as consumer education. For instance, several utilities have used EECLP funds to support the Pay As You Save ® (PAYS®) financing programs described by Lin (2018a).

State and local housing finance agencies have incorporated green building rating systems and associated funding into the construction and retrofit practices of public housing. The federal government spends about $6 billion annually on the LIHTC program, which has supported more than 2 million housing units to date. [47] An analysis of units participating in LIHTC in Virginia concluded that they used 12.5% less energy than non-participating units. "The savings equate to 9.3%, 5.6%, and 3.5% of annual income for extremely low-income, very low-income, and low-income households" (Zhao et al., 2018, p. 559). At the same time, Reina and Kontokosta (2017) note that subsidized housing is less efficient than comparable private-sector housing, perhaps as a result of limited public funding for maintenance and upgrades. Low-income households living in subsidized or public housing units are eligible for participation in WAP.

3.4 STATE PROGRAMS AND POLICIES

Finding: States are using minimum requirements and adders to cost-effectiveness tests to promote greater investment in low-income energy programs.

Many State Energy Offices play active roles in extending energy-efficiency benefits and other energy services to low-income customers. The strong roles that States are playing are described

[45] https://neuac.org/wp-content/uploads/2018/07/1B-Burrin.pdf

[46] https://www.rd.usda.gov/programs-services/energy-efficiency-and-conservation-loan-program

[47] https://betterbuildingssolutioncenter.energy.gov/sites/default/files/PP_Incorporate%20EE%20RE%20Standards%20as%20a%20Criterion%20in%20Tax%20Credits_FINAL_3.pdf

on the Clean Energy States Alliance (CESA) website.[48] The website also has an array of CESA guides, including:

- Bringing the Benefits of Solar Energy to Low-Income Consumers by Bentham Paulos of Paulos Analysis
- Publicly Supported Solar Loan Programs: A Guide for States and Municipalities by Travis Lowder of the National Renewable Energy Laboratory
- Solar+Storage for Low- and Moderate-Income Communities: A Guide for States and Municipalities by Todd Olinsky-Paul.

State and regional resources used to fund these initiatives include the Regional Greenhouse Gas Initiative (RGGI), State Energy Program (SEP), Qualified Energy Conservation Bonds (QEBS), state revolving loan funds, state treasury funding, general obligation bonds, utility ratepayer funds, and environmental settlements funds.

Berg and Drehobl (2018) conducted a survey of 40 of the U.S. states, and concluded that state regulators and State Energy Offices can play a key role in encouraging utilities to carefully consider and expand the role of low-income energy-efficiency programs in their program portfolios. A mix of different strategies have been used. Key among these are (1) setting goals that require minimum levels of expenditure or savings for low-income energy-efficiency programs, and (2) special cost-effectiveness testing and provisions that give extra credit for low-income energy-efficiency accomplishments.

State requirements for goal setting include spending thresholds for low-income energy-efficiency programs, customer participation goals, and savings targets for low-income energy-efficiency programs. Special cost-effectiveness testing and provisions include cost-effectiveness exemptions, quantifying non-energy benefits, and coordination of ratepayer-funded low-income programs with WAP services. While a wide array of diverse state policies is itemized by Berg and Drehobl (2018), the authors also note that 14 of the 15 states with the highest poverty rates do not have either type of policy; many of these states are located in the southeastern U.S.

An increasing number of states are also launching initiatives to facilitate distributed electricity that can contribute to grid resilience. Evens (2015) envisages a future utility-based model where even low- and middle-income households have the option of purchasing power outside the grid, thereby reducing the demand for grid electricity.

3.4.1 Minimum Requirements for Low-Income Energy Programs

Based on a survey conducted in 2017 by the American Council on an Energy-Efficient Economy (ACEEE), more than 20 states have spending or savings requirements for their low-income energy-efficiency programs (Berg and Drehobl, 2018).

In some states, minimum requirements are set by public utility commissions. For instance, one of the most aggressive quotas was set by California's Public Utilities Code Section 382(e) to provide low-income energy-efficiency measures to 100% of eligible and willing customers by 2020 (Berg and Drehobl, 2018). In New York, the Public Service Commission ordered NYSERDA to invest at least $234.5 million of Market Development funds in Low-to-Moderate

[48] https://cesa.org/projects/low-income-clean-energy/

Income (LMI) initiatives for three years beginning in 2016. Thus, the impetus for these minimum requirements can come from state regulators.

State legislators can also be influential. For example, the Illinois Future Energy Jobs Act (FEJA) directed utilities to implement designated levels of low-income energy efficiency. Ameren Illinois Corporation (AIC) was required to spend at least $8.35 million per year (Simms and Casentini, 2018). AIC established a company-wide commitment to increase its energy-efficiency spending, helping underserved communities to participate in the energy-efficiency economy by solidifying relationships with local partners and community-based organizations.

3.4.2 Adders to Cost-Effectiveness Tests for Low-Income Energy Programs

The type and level of cost-effectiveness tests applied to state low-income programs are key factors guiding investment levels. In contrast to traditional residential efficiency programs, low-income programs often seek to address a wider range of challenges beyond simply achieving energy savings; these can include health and safety issues, home durability, arrearage reduction, and electricity terminations and reconnections. For this reason, low-income programs are sometimes not held to the same cost-benefit requirements or thresholds as other types of residential efficiency programs.

A wide range and variety of approaches to evaluate the cost-effectiveness of low-income programs and program measures exists among states. One such approach to give preferential treatment to low-income energy programs, is to exempt the programs entirely from cost-effectiveness tests. Eleven states have specific regulatory or legislative language that formalizes this practice (Berg and Drehobl, 2018). For example, the New Jersey Board of Public Utilities (NJBPU) does not require the low-income Comfort Partners Program to meet any cost-effectiveness requirements. In Minnesota, utilities may opt-out of utilizing cost-effectiveness tests. Minnesota statute 216B.241 directs that "costs and benefits associated with any approved low-income gas or electric conservation improvement program that is not cost effective when considering the costs and benefits to the utility may, at the discretion of the utility, be excluded from the calculation of net economic benefits for purposes of calculating the financial incentive to the utility."

In other states, commonly used cost-effectiveness screening types for low-income programs include the utility cost test (UCT), total resource cost test (TRC), and the societal cost test (SCT), each tailored by regulators and program administrators to meet state-specific policy priorities or goals. An increasing number of states have taken steps to quantify the value of low-income non-energy benefits, while requirements setting specific savings targets for the low-income sector are less common (Berg and Drehobl, 2018). For example, Vermont utilizes the societal cost test as their primary test. A 15% adjustment for non-energy benefits is applied in addition to the cost-effectiveness screening tool for low-income customer programs. The Delaware Energy Efficiency Advisory Council approved the Evaluation, Measurement and Verification (EM&V) subcommittee's proposed estimates of low-income non-energy benefits, which took effect in 2017.[49]

In Pennsylvania, under the Low-Income Usage Reduction Program (LIURP) natural gas utilities are required to devote 0.2% of company revenues towards LIURP services. Electric utilities

[49] http://www.dnrec.delaware.gov/energy/Documents/EMVRegs.FINAL.pdf

collect LIURP funds through a residential distribution cost included in the rates of all residential electric customers. LIURP funding levels are set over three-year periods as part of a utility's Universal Service Plan, which must be approved by the Pennsylvania PUC. Utilities adjust program funding levels for LIURP based on an assessment of the needs of their customer population. LIURP Weatherization measures are selected on the basis of simple payback recovery periods. A simple payback recovery period of seven years or less is required for most measures. Some other measures must meet a twelve-year simple payback recovery period: sidewall insulation, attic insulation, furnace replacement, water heater replacement and refrigerator replacement (Southworth, 2011).

3.5 LOCAL GOVERNMENT, COMMUNITY-BASED, NGO, AND PRIVATELY FUNDED PROGRAMS

Local and community low-income energy programs often focus on opportunities for stimulating economic development, creating liveable-wage jobs, meeting local environmental and sustainability goals, and increasing prosperity by expanding and deepening local collaborations and initiatives. For example, Donovan et al. (2018) used the Wealth Works Value Chain approach to design such programs for communities in upstate New Hampshire. The "Wealth Works" approach was created with funding from the Ford Foundation. It involves value chain coordinators to assist in solving local issues by developing an understanding of the various components of a service, developing and transforming markets, and thereby enhancing a community's prosperity. When applied to energy efficiency, a project would gather information and work with four aspects of the value chain – energy demand, service providers, outside providers and energy supply.

Shoemaker et al. (2018) highlight six energy efficiency programs serving rural areas. Community-based implementation strategies such as "Weatherize" campaigns are overcoming market barriers and accelerating the adoption of energy efficiency in low-income rural communities, Native American villages, and other underserved areas in Northern New England and Alaska (Winner et al., 2018). They are typically supported by loan and rebate programs that resonate in rural areas.

Another trend identified at the local level is the use of environmental settlement funds to support local energy efficiency assistance programs. In Tennessee, the Bristol Energy Efficiency Assistance Program was announced as a part of an environmental settlement in 2014. The program involved coordination between local economic development and community assistance program officials in conjunction with state environmental regulators. Tennessee's State Energy Office worked in partnership with local economic and community development officials to oversee the program's implementation process, coordinate measures and enrolment using existing community assistance programs, and served as technical advisors to local program administrators throughout the project.[50] The Bristol Energy Efficiency Assistance Program partnered with an existing program in the City of Bristol that provided housing repair assistance

[50] https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/special-energy-projects0/redirect---special-energy-projects/city-of-bristol-energy-efficiency-assistance-program.html

to economically disadvantaged homeowners. Through this partnership, a ready-made qualified group of people could be targeted for support under the King Consent Decree funding.[51]

Many cities are developing climate change adaptation and mitigation plans, and many of them consider their impacts on low-income households alongside other equity issues (Barbier, 2014). For example, in Portland, Oregon, the incorporation of equity considerations in the city's climate action plans resulted in a "Climate Action through Equity" plan in 2016. Towns and cities have also organized Weatherize campaigns, modeled after Solarize campaigns, where goals are set and providers are pre-approved in order to foster local participation.[52]

NGOs operate energy and affordable housing initiatives at all scales from the local to the international. For example, the National Center for Healthy Housing (NCHH),) provides guiding documents related to safety, ventilation, moisture control, and thermal comfort, all of which impact energy usage and are particularly pertinent to low-income housing where indoor air quality problems can be severe.[53] The magnitude of philanthropic funding of the totality of these initiatives has not been estimated in the last decade of searchable publications in the Web of Science.

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[51] https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/special-energy-projects0/redirect---special-energy-projects/city-of-bristol-energy-efficiency-assistance-program.html
[52] http://www.greenenergytimes.org/2018/12/17/weatherize-campaigns-spread-across-new-hampshire/
[53] https://nchh.org/information-and-evidence/learn-about-healthy-housing/healthy-homes-principles/

4. THE IMPACTS AND COST-EFFECTIVENESS OF LOW-INCOME ENERGY PROGRAMS AND POLICIES

This section describes the impacts and cost-effectiveness of the many different types of programs and policies that address the energy burdens of low-income households.

4.1 ESTIMATES OF COSTS, BENEFITS, AND COST EFFECTIVENESS

Extensive assessments of the cost-effectiveness of DOE's Weatherization Assistance Program and utility low-income energy efficiency programs have been conducted, and their results are summarized here. The performance of state, local government, and community-based programs has also been documented in case studies and comparative assessments. Some have also benefited from the same level of systematic assessment typical of national programs, including field surveys, inspections, and utility-bill analysis.

4.1.1 Electric and Gas Utility Low-Income Programs

Finding: Low-income energy efficiency programs operated by electric and gas utilities cost more to implement per household and often deliver more critical service given the lack of resources of participants. Based solely on their energy cost savings, these programs are less cost-effective than energy-efficiency programs that serve higher income groups. Low-income energy programs ensure low-income households can benefit from ratepayer funding that they help pay for but would otherwise not benefit from.

The literature documents that the average cost of saving electricity is higher for low-income programs than for other residential, commercial, and industrial programs. For example, Hoffman et al. (2018) examined data spanning 815 program-years of low-income efficiency programs operated by electric utilities from 2009-2015. Their assessment of cost-effectiveness distinguishes between the program administrator cost per kWh saved and the metric when participant costs are included in addition to the program administrator cost. Across all 815 utility programs in the U.S., saving-weighted average program administrator's cost of saved electricity is $0.025 (in $2016) / kWh, and this rises to $0.050 when participant costs are added. For low-income programs, the average program administrator's cost of saved electricity is $0.105 (in $2016) / kWh, and this rises to $0.145 when participant costs are added (Figure 4.1). Low-income participants contribute about 1.3 cents per kWh saved, which is less than in other programs that serve higher income households. This low contribution by low-income customers is consistent with their limited access to financial resources.

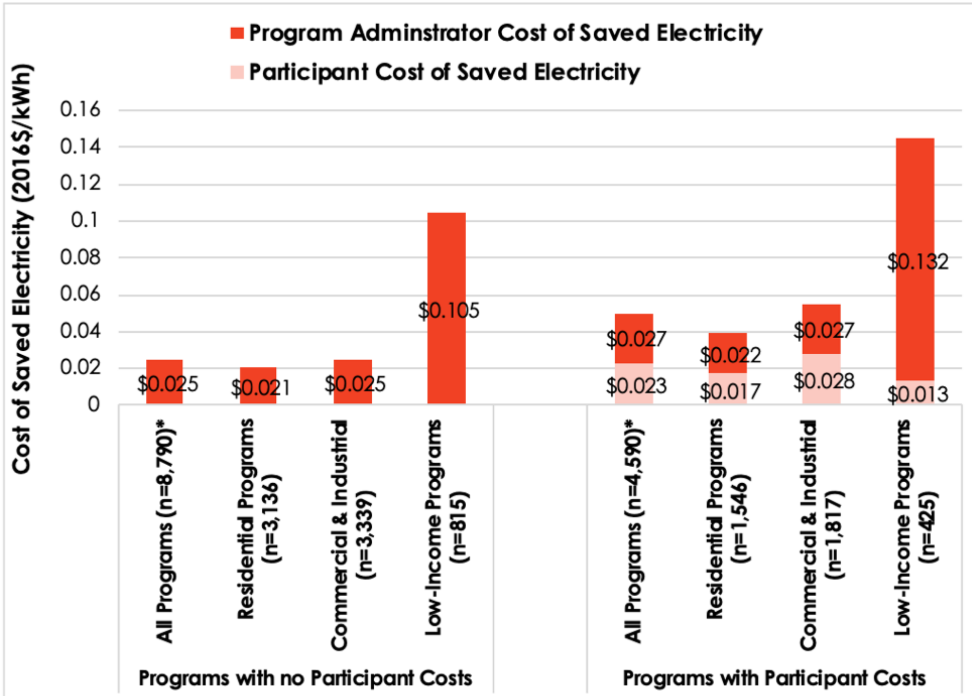

Figure 4.1. Cost of saving electricity in utility energy-efficiency programs.
Source: Redrawn from data published in Hoffman et al. (2018)

4.1.2 DOE Weatherization Assistance Program

Finding: The savings-to-investment ratio of WAP is favorable based on the value of its energy savings alone. The value of the non-energy benefits of WAP and other low-income energy programs are significant.

DOE (2015), Tonn et al. (2014a) and Tonn, Rose, and Hawkins (2018) describe two WAP impact evaluations: one focused on 2008 (before ARRA) and the other focused on 2010, after the Program's funding was significantly boosted by ARRA. The WAP impacts include savings of fossil fuels and firewood as well as electricity (Table 4.1).

The 2008 program supported the weatherization of 97,965 units and reduced energy costs by $340 million over the lifetime of its installed measures. With an average household energy savings of $4,243 and energy measure costs of $2,899, the savings-to-investment ratio (SIR) for the energy measures is 1.4. The 2010 program supported the weatherization of about 340,000 units, reducing energy costs by $1.2 billion and resulting in an energy-based SIR of 1.0. Environmental, health, and household related benefits were found to be significant in both program evaluations. The 2008 program evaluation results are indicative of the program generally and today because the funding during the ARRA period was an order of magnitude greater than normal and occurred in a condensed timeline.

When communities can enjoy more energy-efficient utilities, they derive a variety of benefits including improved public health, higher investment in the local economy, poverty alleviation and sometimes job creation with weatherization policies.

Table 4.1 Summary of benefits from weatherization assistance program in 2008 and 2010
(Sources: Tonn et al., 2014a; DOE, 2015; Tonn et al., 2018)

Program Wide Benefits for All Housing Types		
	2008	2010
Total Homes Weatherized	97,965	340,158
Average Cost per Weatherized Home	Total Cost: $4,695 DOE Investment: $2,301	Total Cost: $6,812 DOE Investment: $5,926
Average Energy Measure Costs	$2,899	$3,545
Energy Savings Per Household (Present Value)	$4,243	$3,190
Total Energy Savings (Present Value)	$340 million	$1.2 billion
Savings-to-Investment Ratio	1.4[i]	0.98[ii]
Total Benefits per Household Including Health & Safety (Present Value)	$13,550	$13,167
Carbon Reduction	2.25 million metric tons	7.38 million metric tons

Savings-to-Investment Ratio for Submarkets		
	2008	2010
Single-Family Homes	1.72	1.12 (0.82-1.53)*
Mobile Homes	1.03	0.79 (0.66-0.79)
Small Multifamily	1.60	
Large Multi-Family (New York City only)	1.82	0.67 (0.55-0.84)

[i] These values include funding from some non-DOE sources that are not uniformly subject to DOE's Savings to Investment Ratio (SIR) requirement that is used to guide the measures that are installed. These funds are often used for more costly energy measures that result in lower SIRs for the combined funds.

Tonn et al. (2018) found that the energy savings vary by housing type, with site-built homes saving more than mobile or multi-family homes. Costs and benefits were also influenced by fuel type and climate zone.

A limited number of studies estimate the potential of a "rebound effect" in low-income houses. The concern is that participants in energy-efficiency programs may increase their use of energy services after their home is retrofitted, reducing or potentially negating any energy savings. In an evaluation of households participating in WAP, Tonn et al., (2015) conclude that this effect is negligible based on surveys of behavior pre- and post-weatherization.

4.1.3 State Green Building Policies

Longitudinal analysis has been used in a few studies to examine the time effects of state green building policies (operating independently of WAP) on the energy performance of low-income housing units. In one case, Zhao et al. (2018) evaluated monthly energy use data over three years from 310 residential units across 16 developments in the State of Virginia and conducted profile analysis and multivariate analysis of variance (MANOVA). Their results estimate financial savings of $648 per year due to reduced energy usage in green buildings. These savings equate to 9.3%, 5.6%, and 3.5% of annual income for extremely low-income, very low-income, and low-income families, respectively, suggesting that green building incentives and practices can enable housing with affordable energy systems. The broader goal of affordable housing is a much bigger issue tied to regional economics, housing vintage, and many other factors. Energy is just one piece of the poverty puzzle; making energy more affordable and sustainable is important but not a complete solution to the poverty problem.

4.1.4 Community Partnerships

Local partnerships in some states and communities, such as those supported by the DOE initiative called the Clean Energy for Low Income Communities Accelerator (CELICA), have been designed to take a more holistic approach to energy affordability. It required partnerships across different levels of government agencies, where DOE provided assistance to states and local governments on the design and implementation of low-income energy programs. CELICA not only provided support to reduce energy burdens, but also provided tools for managing and monitoring progress (DOE, 2017). Taking a broader perspective, CELICA not only leveraged the Weatherization Assistance Program and its network of providers to expand access to energy efficiency for low income households beyond what federal funding could address, but also promoted distributed renewables to provide stability from rising energy costs, promoted economic development, and improved the environment.

4.2 UNDER-SERVED LOW-INCOME COHORTS

Evidence suggests that three cohorts have been under-served by efforts aimed at addressing the high energy burden of low-income households: multifamily and rental markets, rural communities, and manufactured and mobile homes.

4.2.1 Multifamily and Rental Markets

Finding: The multifamily low-income market has been difficult to reach with traditional energy-efficiency programs due partly to misalignment of incentives. New program designs that address split-incentives and incorporate strong community engagement can help reach multifamily markets. Strong community engagement can expand participation rates and enhance the success of low-income energy programs. Public-private-philanthropic-partnerships and interagency coordination and leveraging can reduce energy costs for low-income households while also delivering non-energy benefits.

Multifamily buildings are home to nearly 25% of the U.S. population and more than half of low-income households (Hernandez et al., 2016; Corso, Garascia, and Scheu, 2017; Frey et al., 2015).[54] Based on the 63,166 housing units occupied by low-income households that were examined by Hernandez, et al. (2016), the percentage of low-income households living in multifamily housing is 51.9%. Specifically, 32,824 (36.6%) of the 63,166 units were either an attached house or were located in a small apartment building, and 9,725 (15.4%) were located in a large apartment building. For a variety of reasons including high land values, cities and urban areas have a disproportionate number of multifamily buildings (Hernandez and Philips, 2015).

With high rates of various vulnerabilities and a lack of access to housing improvements, households in low-income multifamily housing face disproportionate health and financial

[54] https://www.energy.gov/eere/slsc/maps/lead-tool

challenges (Fabian et al., 2012; Waite et al., 2018) At the same time, these households are often underserved by traditional energy-efficiency programs (Ross, Jarrett, and York, 2016; Berkland et al., 2018). In Program Year 2008, WAP funds supported the weatherization of 97,965 units; 23% of these lived in multifamily buildings (18% large and 5% small multifamily structures) (Tonn, 2014a). These markets have been hard to reach by traditional utility and government programs (Corso et al., 2017; Henderson, 2015). A major reason is that incentives are misaligned as a result of a "principal-agent" or "split-incentive" problem. When tenants pay the energy bills, the building owner may not be motivated to invest in improvements because the bill savings accrue to occupants (Reina and Kontokosta, 2017).

Considering their high concentration, these markets represent a significant potential for energy and cost savings and for improving people's lives including the quality of the air they breathe (Chant, Schaaf, and Ast, 2016; Henderson, 2015; Frey et al., 2015). Further, government control over multifamily units that form part of public housing makes it possible to integrate different policies (Reina and Kontokosta, 2017). The consensus appears to be that there is a need for scaling up the energy-efficiency and related improvement programs for multifamily and rental markets (Samarripas, York, and Ross, 2017).

Different types of energy-efficiency programs have been implemented to address low-income multifamily market needs. These include programs led by utilities and NGOs; financing programs (Leventis, Karmer, and Schwartz, 2017); and data collection programs (Long et al., 2018). Several lessons can be found in the reports and studies we analyzed. Community support is particularly useful in multifamily programs (Chant et al., 2016; Sanchez, Levine, and Tajina, 2018). In two cities in Ohio, Andrews and Poe (2018) found that local community involvement led to increased participation, ultimately leading to improvements in health and safety for tenants as well as landlords. Similarly, community based social marketing can increase the success of programs (Keilty, 2018). Carefully designing the incentives and utility-managed on-bill financing can help address the problem of misaligned incentives (Bird and Hernandez, 2012). Finally, by integrating energy efficiency into solar projects, energy burdens can be significantly reduced (Samarripas and York, 2018)**.**

4.2.2 Rural America, Island Territories, and Indian Reservations

Finding: Low-income households in rural communities often spend as much as a quarter of their income on energy due partly to the low-density built environment enabled by lower land values. Assistance from local community programs and organizations are particularly critical to success in these markets.

Energy burdens in rural communities are estimated to be as high as 25% (Ross et al., 2018). Thus, rural communities may have the greatest need for energy-efficiency programs. The distribution of burdens in rural areas largely reflects the socio-demographic patterns in the rest of the country with minorities, elderly, and renter households spending a higher share of income to meet utility bills (Ross et al., 2018). This problem can be even more pronounced for island territories (Winner et al., 2018). Rural areas present unique challenges for implementing energy efficiency programs; they are less densely populated, typically have a different fuel and consumer mix, different regulatory structures, and high program implementation costs (Shoemaker et al., 2018). Lower densities can make it difficult to access energy-efficiency programs, and result in higher costs of providing infrastructure including pipeline infrastructure to support the conversion of electricity, fuel oil, kerosene and other fuels to natural gas, which is often the least-cost fuel for home heating (Ross et al, 2018).

Native American reservations have similar characteristics and account for some of the highest rates of energy poverty in the U.S. Their un-electrified homes span the contiguous United States and Alaska (Begay, 2018a). Provision of energy access to remote areas in the reservations at affordable rates has been a challenge for the traditional electricity development model. Looking to the future, these reservations have a lot of promise because they represent 2% of the U.S. landmass but 5% of the renewable energy resources (Begay, 2018a). Harnessing these resources can be a way of rejuvenating the economies of rural communities (DeSilva, McComb, and Schiller, 2016; Donovan et al., 2018). The rooftop solar solution the Navajo Nation has adopted in collaboration with Sandia National Laboratories offers insights into how the Navajo Tribal Utility Authority's work could serve as a residential model to meet the needs of the 1.2 billion people globally who are without electrical residential power.

Several programs have been piloted and rolled out to reduce energy burdens and increase access in these communities over time. These involve direct funding from government programs, NGO involvement, and funding from charitable organizations. Different agencies are responsible for implementing these projects, including State Energy Offices, electric cooperatives, municipal or investor owned utilities (Donovan et al., 2018; Shoemaker et al., 2018).

Results and findings from pilot projects and other programs focused on rural areas show that gains from targeted rural energy-efficiency programs can be increased by using cooperatives in remote rural locations (Lin, 2018a). This is especially true if the financial support can be earmarked to meet upfront costs and to address the challenge of split incentives. Similarly, community-based programs where partnerships with NGOs is leveraged are also found to be successful (Andrews and Poe, 2018; Donovan et al., 2018). There are significant gains to be made from pooling resources from different projects to achieve economies of scale, and from training workers to operate these new systems (Souba and Mendelson, 2018). It has been estimated that strategies to tackle the energy-efficiency gap in rural and small-town America could reduce energy burdens by as much as 25% (Ross et al., 2018).

4.2.3 Manufactured and Mobile Homes

Finding: The opportunity to address the high energy burdens of low-income households occupying manufactured housing has received limited analysis and policy focus.

This oversight is related to the limited attention given to the energy-efficiency gap in rural America, where 70% of all manufactured homes are situated. Manufactured homes made up 9% of new U.S. homes in 2017 and housed more than 20 million people in total.[55] Manufactured homes consume 35% less energy than other homes due to their smaller footprint, but unfortunately residents spend 70% more per square foot on energy (Ross et al., 2018). With a median family income of $30,000, residents of manufactured homes have higher-than-average energy burdens.[56]

[55] https://www.manufacturedhousing.org/wp-content/uploads/2017/10/2017-MHI-Quick-Facts.pdf.
[56] https://aceee.org/blog/2016/08/mobile-homes-move-toward-efficiency

4.3 TECHNOLOGIES AND MEASURES INSTALLED

Finding: Health and safety upgrades are not components of most utility low-income energy-efficiency programs. Information and communication technologies such as smart thermostats support low-cost behavioral approaches to improving energy efficiency, but they tend not to be incorporated into low-income energy programs.

Through its Grantees and its network of hundreds of Subgrantees providing services at the local level, WAP installs energy efficiency measures and a limited amount of energy-related safety/health measures at no financial cost to homeowners. Air sealing and insulation are the two most common measures (Figure 4.2). Some utilities also use contractors to directly install measures. The most common measures installed by contractors under electric utility programs are lighting, air sealing, insulation, and water heater upgrades, typically at no financial cost to the household. Some utilities also offer energy-savings kits with weatherstripping, caulking, LED bulbs, and other low-cost items that homeowners can install themselves.

Drehobl and Castro-Alvarez (2017) found that the majority of cities have access to utility programs with lighting, air sealing, and insulation measures, while smart thermostats and health and safety measures were the least common program measures. In terms of cost-effectiveness, Elsawaf, Abdel-Salam, and Abaza (2013) found that that air-source heat pumps could reduce heating costs in low-income mobile homes by up to 52% when integrated in an electric strip heat system, while also improving thermal comfort in their analysis of eastern North Carolina. They also found that their benefits exceed the initial cost of installation.

Other studies have also documented co-benefits and savings from building improvements. For example, the health and financial benefits of replacing old windows with thermally efficient windows have been documented by Jacobs et al. (2016), who conclude that in addition to saving energy costs, window replacement programs can also reduce the potential exposure to lead from degraded lead paint mixed in soil and dust.

Bradshaw et al. (2016) investigate the benefits and cost-effectiveness of three types of weatherization treatments: replacing a standard thermostat with a programmable thermostat, installing attic insulation, and envelope air sealing. These treatments were modeled for the low-income housing stock of six contrasting American urban areas: Orlando, Florida; Los Angeles-Long Beach, California; Seattle, Washington; Philadelphia, Pennsylvania; Detroit, Michigan; and Milwaukee, Wisconsin. Results show that (1) regional variations have high impact on the cost-effectiveness of weatherization treatments, (2) housing stocks with substantial electric space conditioning tend to offer greater energy cost and greenhouse gas (GHG) savings, (3) the effect of a GHG price is small compared to energy cost savings when evaluating the cost-effectiveness of weatherization treatments, and (4) installing programmable thermostats is the most cost-effective treatment of the three treatments studied. This study highlights the importance of thoughtful consideration of low-income energy-efficiency program goals when selecting cities or regions to prioritize because different goals suggest different approaches.

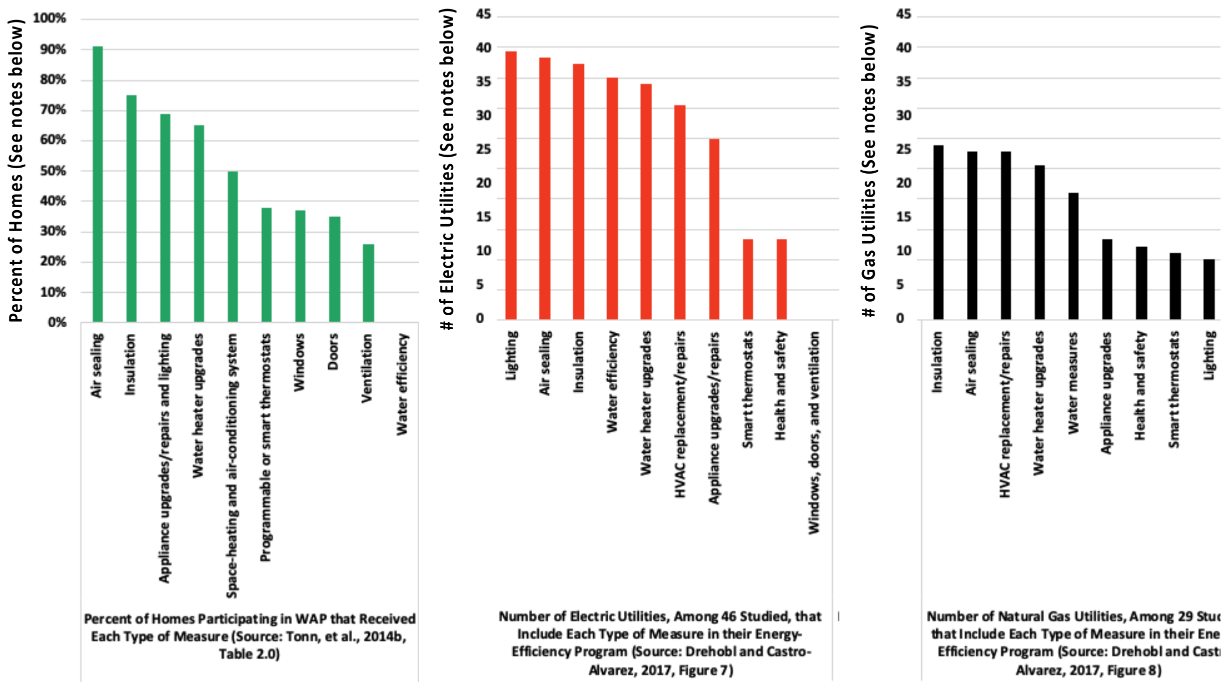

Figure 4.2. Measures installed in low-income programs.
(Source: Authors, based on data from Tonn et al., 2014b; Drehobl and Castro-Alvarez, 2017)

Verclas and Hsieh (2018) looks at disconnection policies of utilities that make households vulnerable to energy insecurity. The data on disconnections by utilities is not easily available. The authors look at Minnesota and Iowa and identify the policies in place to help customers maintain access to energy resources.

4.4 THE ENERGY SAVING POTENTIAL OF LOW-INCOME HOUSHOLDS IN THE U.S.

In a study of the 48 largest cities in the country, Drehobl and Ross (2016) estimate that if the low-income housing stock were brought up to the efficiency level of the average U.S. home, 35% of the low-income energy burden could be eliminated.

Focusing specifically on possible electricity savings from weatherization, Hoffman (2017) assessed the implications of pursuing energy efficiency neighborhood-by-neighborhood where low-income households are prevalent. Using data on demographics, housing types and recent savings from low-income retrofits, and assuming that households at 200% of the Federal Poverty Level are eligible, Hoffman (2017) provides rough electricity savings estimates of 51.5 billion kWh. A majority of these savings are in the South (54%) and in hot-humid climate zones (38%), where much of the nation’s poverty is concentrated.

5. PROMISING PRACTICES

5.1 SOLAR ENERGY FOR LOW-INCOME HOUSEHOLDS

Finding: Expanding the technology scope of low-income energy-efficiency programs to include solar PV, smart meters, storage, and electric vehicles could significantly improve energy affordability for low-income households. Broadening finance and administrative options (e.g., on-bill program designs) could also expand savings opportunities.

Historically, affluent households have dominated the market for residential solar installations, but with expanding production and declining costs, solar systems are now beginning to reach previously underserved markets. In low-income communities, solar energy can significantly reduce energy burdens, while also generating living-wage jobs. By displacing pollution from traditional sources of energy, solar can also mitigate disproportionate negative environmental impacts on low-income communities (Franklin and Osborne, 2017). Despite these perceived benefits, disparities across the country in the adoption of solar resources continue to persist; this continuing gap can be attributed to social, political, and economic factors, as well as the structural integrity of roofs and the soft costs of running programs (Kann and Toth[57]; Tidwell, Tidwell and Nelson, 2018; Gupta et al., 2018b; Zhang et al.[58]; Sunter et al., 2019). Typically, there has also been a trade-off between reducing bills for low-income households and ensuring returns for utilities (Aznar and Gagane, 2018). Further, the growing adoption of solar by affluent households can potentially reduce sales for utilities and disproportionately affect the share of fixed utility costs that low-income households have to bear.

A detailed analysis of solar adoption presents some interesting patterns of diffusion of solar technology at local and household levels. In their study of solar PV in Connecticut, Graziano and Gillingham (2014) find that the number of previously installed solar systems, and characteristics of the built environment significantly predict adoption of PV systems. This corroborates findings that peer influences, community effects, and word-of-mouth strongly influence solar adoption (Bollinger, Gillingham, and Tsvetanov, 2016; Gillingham and Bollinger, 2017; Gupta et al., 2018a).

Federal and state programs focused on addressing energy poverty have traditionally helped deploy weatherization and bill assistance programs; however, coupling these services with solar financing assistance presents a potentially attractive way to more dramatically reduce the energy burden of low-income households (Ulrich et al., 2018). The Navajo Nation provides a vivid example of rooftop solar systems being installed to tackle energy poverty among its 35,000 remote off-grid Native American members, with dispersed housing, where solar PV rooftop systems are providing a viable solution to this rural electrification dilemma (Begay, 2018b).

Despite the expanding penetration of low-income solar systems, research to date has not yet fully assessed what proportion of low-income housing is suitable for solar PV or what fraction of low-income electricity needs could be met by solar systems (Sigrin and Mooney, 2018). Such assessments need to consider the barriers that make it difficult for low-income households to acquire solar resources, such as:

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[57] https://www.woodmac.com/our-expertise/focus/Power--Renewables/How-Wealthy-Are-Residential-Solar-Customers/
[58] https://beccconference.org/wp-content/uploads/2018/10/jingjang_presentation2018.pdf

- **Access to capital and lower credit ratings.** Investments in solar installation can be prohibitive for low-income families, due to their high cost. This segment of the population can establish a power purchase agreement with a third party to avoid the high upfront cost. However, third parties are likely to reject a low-income customer if they have a low credit score.[59]
- **The landlord/tenant split incentive.** Given that multifamily buildings represent a significant portion of the housing property portfolio, they present an important opportunity for the growth of rooftop solar (Inskeep, Daniel, and Proudlove, 2015).
- **Lack of information and language problems.** Low-income families for whom English is a second language can have trouble making informed decisions about solar installations because of language barriers that impede learning about the benefits of solar technologies (Paulos, 2017).
- **Housing conditions.** To install solar, roofs must have 10-15 years of remaining life, which is rarely the case in low-income housing. Structural repairs, plumbing, insulation and roof maintenance are often more pressing priorities for low-income residents.[60]

The federal government's Investment Tax Credit is one of the most powerful policies currently promoting solar investments in the U.S., but it is inaccessible to most low-income households who typically have limited tax liability.[61] Paulos (2017) estimates that securing a 30% credit on a $10,000 solar installation would require a taxable income of at least $26,000.

Traditional utility net metering and solar deployment subsidies also have issues of fairness. Under typical rate structures, net metering shifts costs from solar owners to lower-income ratepayers (Johnson et al., 2017). At the same time, the rapid deployment of rooftop solar systems has raised concerns about the fair distribution of electricity costs through rates (Franklin and Osborne, 2017). Distributed solar programs raise rates, while their subsidies go disproportionately to affluent households. Further, if not accounted for properly, increase in solar penetration can also lead to operational and financial challenges and consequently, result in reduction in the potential environmental benefits (Padhee and Pal, 2018). As with energy efficiency and electric vehicle programs, low-income households have notably low rates of participation in solar programs (Ulrich et al., 2018).[62] A recent national assessment of residential rooftop solar technical potential estimates that low-income housing accounts for approximately 25% of the nation's total technical potential.[63] It should be noted that some low-income households may not be able to participate in solar programs if the building roofs are older and not structurally sound.

At the same time, because of their high levels of energy burden, low-income households are more severely impacted by rising electricity rates compared with other "non-participants" who typically have lower energy burdens. Because some form of dynamic pricing is currently available to most residential customers in the U.S., most low-income households can take advantage of them. The goal of dynamic pricing is to provide accurate price signals so that customers will be motivated to reduce their consumption during hours when the utility is

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[59] http://www.gridalternatives.org/sites/default/files/Low-income%20solar%20policy%20guide%20press%20release_FINAL.pdf
[60] http://www.gridalternatives.org/sites/default/files/Low-income%20solar%20policy%20guide%20press%20release_FINAL.pdf
[61] https://www.taxpolicycenter.org/taxvox/new-estimates-how-many-households-pay-no-federal-income-tax
[62] https://emp.lbl.gov/publications/income-trends-residential-pv-adopters; https://www.woodmac.com/our-expertise/focus/Power--Renewables/How-Wealthy-Are-Residential-Solar-Customers/
[63] https://www.nrel.gov/docs/fy18osti/70901.pdf

experiencing high-priced peak demand. The most common dynamic pricing for residential customers is time-of-use (TOU) rates, where utilities set electricity prices for different time periods in advance. The rates for each time block are usually adjusted two or three times each year to reflect changes in the demand and wholesale market (Brown, Zhou, and Ahmadi, 2018).

For example, to accommodate for high levels of distributed generation and peak hours that are shifting from the afternoon to the evening, California has adopted default TOU rates that have shifted to later peak pricing periods. Waite et al. (2018) shows that these new TOU rate structures in California can increase energy cost burdens and have adverse consequences for low-income customers. Similarly, a randomized experiment conducted in the southwestern U.S., demonstrated that TOU rates can disproportionately increase the bills of households with elderly and disabled occupants, which, for a variety of reasons, may be less able to shift their consumption to low-cost hours of the day (White and Sintov, 2019).

The same fairness concerns would appear to apply to EV rates offered by utilities, where night-time purchasing of electricity by EV owners is offered super-off-peak pricing, which subsidizes electricity usage for those who can afford EVs.

One study of New Jersey solar data, PJM market data, and demand profiles from a PJM utility investigated rate and bill impacts of large-scale solar penetration (Johnson et al., 2017). It concluded that the fear of a utility "death spiral" and significant rate impacts may be exaggerated. Significant solar can be incorporated with only a 2% increase in non-participant bills. On the other hand, at high levels of penetration, distributed solar has the potential to alter the system peak hour which affects the allocation of costs across rate-classes. As the peak hour shifts to the evening when solar production diminishes, residential customers, in particular low-income households, face higher distribution costs. Policy makers and utilities need to be aware of these challenges in designing the next generation of rates that are better aligned with cost causality. Ronen, Gai, and Crampton (2016) find that repurposing the existing programs to cover the cost of rooftop solar could reduce electricity bills for low-income households by about $9,000 over the lifetime of solar systems. (The authors do not discuss the maintenance and repair costs of the system.)

Programs are emerging that target barriers to solar installations for low-income households. They can be divided into rooftop solar programs and community solar initiatives.

5.1.1 Rooftop Solar Programs

"Solarize" and "Solar for All" campaigns have been popular models for promoting rooftop solar. In general, Solarize campaigns aim to remove barriers and headaches of installing solar in residences (Cook, 2014), while "Solar for All" programs typically include incentives for solar panels so that low-income households can afford to install them. Both models support the creation of "prosumers" who generate and export solar power, thereby reducing their energy bills and burden. The magnitude of electricity bill reductions depends on the utility's net metering. Another type of program integrates solar panels into low-income home retrofits, and sometimes electric vehicles are part of the expanded program.

"Solar for All" programs typically aim to install PV systems in low-income households and to provide grants to other organizations with similar goals. For example, the Washington DC's

“Solar for All” program is funded by DC’s Department of Energy and Environment and plans to install solar PV systems on more than 6,000 low-income homes annually with a goal of reaching 100,000 low-income households by 2032. This program helps lower the energy burden of its low-income households and contributes to accomplishing its renewable energy goals. [64]

Another sizeable community-led solar aggregation and energy efficiency program is targeting low-to-moderate-income residents of Northern Manhattan (Roundtree, 2018). A community-led Energy Democracy Working Group (EDWG) selected and evaluated solar installers and is coordinating with the Housing Development Fund Corporation to reach co-op residents who are predominantly low to moderate income people of color. The project team also works with solar installers and the EDWG to promote local job creation related to the initiative.

California’s Multifamily Affordable Solar Housing Program shows that subsidized efforts can bring solar resources successfully to multifamily housing. MASH targets multifamily housing and was created under the California Solar Initiative bill enacted in 2006. Homes must be using either Pacific Gas and Electric, Southern California Edison, or San Diego Gas and Electric as their utility provider. Customers must also have an occupancy permit of two years or more. This program provides fixed, upfront payment based on the system’s potential capacity. Incentives for these multifamily homes are all Expected Performance Based Buydown (EPBB).[65] As of July 2017, the program has contributed 33.75 MW of interconnected solar capacity, successfully operated 427 projects statewide in multifamily low-income housing, and paid $95 million in incentives to customers (Coughlin, Irvine, and Johnson, 2013).

Several case studies have shown that risks associated with installing solar on affordable housing can be mitigated by leveraging investments in energy efficiency (Samarripas and York, 2018). Two Michigan communities took advantage of additional WAP-ARRA-funding through the Sustainable Energy Resources for Consumers Grants (SERC) to expand weatherization to include solar. Their efforts concluded that renewable energy may have additional quality of life benefits to offer families beyond the cost savings (Walton, 2014). Similarly, Colorado and New York State have initiated efforts to hybridize weatherization with solar investments in WAP projects; and in a few states, LIHEAP rules allow weatherization projects to incorporate PV as an option to reduce household energy burden (Ulrich et al., 2018). Evidence of cost effectiveness of this energy-efficiency and renewable energy combination has emerged from the efforts of the Colorado Energy Office in a state with high solar irradiance. In their evaluation of the CEO’s efforts, Cook and Shah (2018a) found that regardless of the type of energy-efficiency improvements, incorporating PV as a measure to reduce the cost of electricity cuts customer bills by $400 or more annually. (This is without taking into account the maintenance costs of the system.) Integrating electric vehicles can reduce costs further, as in the Single Family Affordable Solar Housing (SASH) pilot program (Verclas, 2018), and Vermont has also hybridized all three types of measures – energy efficiency, solar, and electric vehicles – with home energy storage. Further, as in the case of energy efficiency programs, community organizers can also play a role in encouraging pro-social behaviors (Kraft-Todd et al., 2018; Wolske, Stern, and Dietz, 2017).

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[64] https://doee.dc.gov/solarforall

[65] The EPBB is an up-front incentive payment where the incentive amount is adjusted to reflect verifiable system capacity as well as the effect of system orientation and shading on energy production. https://www.cleanpower.com/wp-content/uploads/2012/02/008_EPBB_IncentiveStructure.pdf

Finally, the fact that solar is approaching cost-parity in many areas and can improve the resilience of housing, has led to its increasing role in disaster recovery efforts across the country including the Caribbean Islands. The FEMA Disaster Recovery Act and HUD Community Development Block Grant-Disaster Recovery (CDBGDR) program now have more funding dedicated to solar installations in light of this. DOE and HUD are also implementing solar and energy storage in disaster prone areas for low-income households (Source: DiRamio, Personal Communication, September 2019).

5.1.2 Community Solar Programs

Community-solar helps low-income households take advantage of solar projects by allowing them to purchase a small portion of as little as one panel of an offsite, local solar array in exchange for reductions to their utility bill for the entire life of the solar system (Booth, 2014). Sometimes called “shared solar”, community solar refers to local solar facilities shared by multiple subscribers. Community solar is particularly suitable for low-income renters and multifamily residents who can access solar via two alternative business models (IREC, 2018). With on-site shared solar, energy generation credits can be purchased from a single solar system that is shared virtually among multiple tenant accounts. With off-site shared solar, multiple remote customers can receive credits on their various utility bills for the shares they own in a common system. In sum, community solar provides three benefits. It can make solar accessible to homeowners without a rooftop and to renters, it can be easily transferable, and it may reduce replacement risks for on-site solar systems.

The state level policies on solar vary across states. While many states have some type of policy initiative to support the adoption of community solar, most of these are one-off policies rather than state-wide programs. In the absence of state-led programs, voluntary and utility-led programs are unlikely to reach underserved communities (Vote Solar, 2018). Community solar programs in the U.S. have at least four distinct ownership and management arrangements. In a utility-sponsored model, shares are offered to electric ratepayers. In a special purpose entity model, community investors can receive a return on investment (ROI) and offset their personal electricity use. In a non-profit model, donors contribute to a non-profit that owns the community installation. In a community-shared model, a third-party solar vendor owns the facility and community members sign up to be a part of the solar campaign (Coughlin et al., 2013). Several of these have served low-income multifamily residents, including one non-profit model used by the Co-op Power in New York and two utility-sponsored models including California’s Multifamily Affordable Solar Housing (MASH) and a Maryland PSC pilot program. Like many Solarize programs, Solarize Mass-Somerville is a community solar model that does not have an income qualification (Coughlin et al., 2013). It is available for low-income households, who otherwise would be unable to purchase rooftop solar.

Thus, administrators of low-income programs are learning from models that have successfully served higher-income customers and are creating new types of business models that are adapted and evolved to meet the needs of low-income households (Chan, Ernst, and Newcomb, 2017; Cook and Shah, 2018b; Heeter et al., 2018). However, the applicability of these strategies to low-income markets depends on the type of housing and the ownership status. As a result, Cook and Bird (2018) identified 13 different financing options that could be deployed for low- and moderate-income customers, each with its own unique features and impacts. Policymakers need to weigh the pros and cons of each type when considering applicability to their low-income communities. IREC (2016) recommends using alternative financing tools such as anchor subscribers and back-up guarantees, direct and tax incentives, loan programs and credit enhancements, and low-cost public financing.

An interesting finding is that utilities are motivated to develop community solar not only to satisfy consumer demand or meet regulatory requirements for renewable energy, but also to alleviate revenue losses related to residential solar PV adoption (Funkhouser, et al., 2015). When net metering of rooftop solar power is set at retail rates, homeowners with rooftop systems pay significantly lower bills and do not pay for all of their associated fixed costs that the utility incurs. In a sense, they become "free riders", relying on non-participants to cover the fixed charges that they once pay for before installing their solar system (Funkhouser, et al., 2015). Community solar can be designed to keep the utility "whole" with respect to collecting revenues to cover its fixed costs.

Thus, it would appear that community solar for low-income households could thrive because it benefits the business model of the incumbent energy stakeholders – the electric utilities. At the same time, as community solar models get adopted widely, there is a potential for "community washing." It is unclear if the positive consequences of community solar will be experienced by participating communities, or if benefits will dis-proportionately be enjoyed by utilities or solar developers (Ptak et al., 2018). In addition, to foster the continued adoption of community solar, projects need to be financially beneficial for low-to-moderate income families (Vote Solar, 2018).

Despite the expanding penetration of low-income solar systems, research to date has not yet fully assessed what proportion of low-income housing is suitable for solar PV or what fraction of low-income electricity needs could be met by solar systems (Sigrin and Mooney, 2018). Such assessments need to consider the barriers that make it difficult for low-income households to acquire solar resources.

5.2 LEVERAGING THE HEALTHCARE BENEFITS OF ENERGY-EFFICIENT HOUSING

The healthcare industry has the potential to be a strong ally in the effort to reduce the energy burdens of low-income households. Problems associated with high energy burdens often include adverse health effects. Insufficient heating and cooling systems and leaky homes can cause hypothermia and heat stress. Improper air filtration, cracked heat exchangers, and poor ventilation can exacerbate asthma and other respiratory problems for occupants (Batterman et al., 2012; Doll, Davison, and Painting, 2016). Air conditioning units can transmit bacteria and lead to increased infection rates. Additionally, medical conditions often require electricity for treatment and medicines, such as diabetics needing refrigeration for insulin and those with breathing-related complications needing electrically powered breathing assistance devices. If updates to infrastructure are too costly and energy burdens are too high, households can end up sacrificing their health in order to cope with their energy bills. This in turn can lead to higher healthcare costs that further exacerbate the expenditure burden of households and lead to chronic stress (Hernandez et al., 2016).

The physical and mental health benefits of energy-efficiency upgrades are well documented (Camprubi et al., 2016; Fabian et al., 2012, 2014; Frey et al., 2015; Leventis et al., 2017; Coombs et al., 2018; Tonn et al., 2018). Surveys and case studies of residents systematically identify favorable health effects (Hernandez and Philips, 2015; Hernandez et al., 2016). Based on the self-reports of public housing residents, Jacobs et al. (2015) found that green and healthy housing produced health benefits; specifically, there were reduced rates of hay fever, asthma, headaches, sinusitis, respiratory allergies, and angina. The latest WAP evaluation indicates that the value of the program's health benefits are significant (Tonn et al., 2018).

Collaboration and co-funding across the energy and healthcare industries offer an opportunity for both industries – and the vulnerable populations they serve – to benefit. The healthcare industry, and in particular Medicaid and Medicare and those states with value-based healthcare, have a vested interest in supporting healthy homes for low-income households that reduce medical costs. The energy industry often cannot invest in energy-efficiency measures or install rooftop solar systems without first making structural and safety investments (Breysse et al., 2011). Co-funded programs can leverage the potential benefits to both sectors (Kravatz et al., 2018; Ulrich et al., 2018). By combining health and safety housing improvements with efficiency retrofits using established energy-efficiency programs, the cost-effectiveness of efficiency investments can be strengthened. Spillman et al. (2016) provides examples of state initiatives where Medicaid funding has been used to make improvements, some of which are also energy-efficiency measures, and to educate residents about the health benefits of home energy upgrades. Healthy home measures include cleaning air conditioners and vents, improving HVAC systems, installing standalone air filters, plugging air leaks, and better insulation. By expanding the labor force of energy retrofit and public health professionals serving vulnerable populations, both stakeholder industries can improve (Dryden, et al., 2018).

5.3 BEHAVIORAL ECONOMICS AND SOCIAL SCIENCE APPROACHES

The study of low-income energy burdens is beginning to benefit from the emergence of behavioral economics and social-psychological approaches to understanding energy behavior.

Behavioral economics is the application of lessons from psychological and experimental studies to “nudge” people to change their behaviour. Well established concepts in behavioral and experimental economics on principal-agent problems, information asymmetry, and bounded rationality inform this research (Allcott and Rogers, 2014; Brown, 2001; Simon, 1976). However, most of these analyses do not focus specifically on low-income households. As a result, there is deep uncertainty about likely responses to information feedback, incentives, and an array of other policy interventions, and program offerings. Extant studies analyze the role of behavioral economics in determining and nudging people’s energy choices (Allcott and Taubinsky, 2015; Chetty, 2015; Sunstein and Reisch, 2014). Behavioral motivations may include monetary gains, information campaigns, education programs, audits and energy reports (Drehobl, Chikumbo, and Tanabe, 2018). The studies span a range of themes – behavioral response to energy efficiency, using green vs grey energy, willingness to pay, and community-based programs (Allcott and Taubinsky, 2015; Chetty, 2015; Sunstein and Reisch, 2014). As noted earlier, the incongruence between households’ values and intrinsic and extrinsic factors can limit their ability to adopt energy saving activities. This gap is especially relevant for low-income households, which generally have lower energy literacy than other income groups.[66]

[66] https://nef1.org/wp-content/uploads/2018/11/NEF-National-Energy-Literacy-Survey-White-Paper-181115.pdf

Local governments are introducing programs that encourage behavior change at the consumer level. Several strategies have been adopted to engage residents and low-income households in energy-efficient behavior, chief among them being in-person engagement and education campaigns (Drehobl et al., 2018; Simms and Casentini, 2018; Craig, 2016). Most low-income adults are interested in learning about ways they can save on their electric or heating bills, and this is especially true among women and homeowners (Treadway, 2018). Further, awareness of utility energy-efficiency programs makes consumers more likely to participate in them (Craig, 2016). This finding was based on a large survey of 2,450 residential consumers, which enabled differences across income groups to be examined. The importance of program awareness as a predictor of program participation was found to be significant across all income groups, including households in the lowest cohort with incomes less than $20,000. According to the opinion survey conducted by Treadway (2018), more than 80% of the respondents are interested in learning about ways to save on energy bills and low-income households are concerned about paying late fees and reconnection charges. Further, women, homeowners, and higher income households are more likely to be interested in these programs.

Some studies indicate there may also be high non-monetary costs associated with participation in a weatherization program that affect participation (Fowlie et al., 2015; Hirshfield and Iyer, 2012). Lack of knowledge about the features of different appliances and ineffective targeting can also lead to low uptake of these high-efficiency technologies among low-income households (O'Dwyer, 2013). Effective approaches to address different groups and sub-segments are going to be quite distinct (Treadway, 2018).Low-income program services and outreach messaging need to reflect the critical difference between sub-segments of vulnerable populations in the low-income market, including, for example, single mothers working two jobs, fixed-income senior citizens, and Native American populations returning to reservations (Treadway, 2018).

The limitations notwithstanding, local, municipal, and community level initiatives are likely to have greater success as they are closer to their target communities. Consistent with the findings on multifamily rental markets and rural customers, local engagement programs and partnering with local community-based organizations has significant gains and benefits (Hirshfield and Iyer, 2012; Simms and Casentini, 2018). This is also true in the case of household level usage of gas (Long et al., 2018). Niederberger (2018) suggests using "nudges" to encourage low-income energy consumers to buy energy-efficient products. These nudges would especially be effective in cases where the cost of more efficient products is comparable to their inefficient counterparts, because liquidity and budget constraints could otherwise prevent the purchase of more costly options. Further, designing a marketing model of local programs that take into account the role of behavioral changes by continued engagement, paying attention to customer experience, relying on strong stakeholder communication, and using interactions that allow for actionable information to be exchanged are all useful lessons for future program implementation (Keilty, 2018). Donovan, Bleything, and Enterline (2014) also note the potential for increasing energy efficiency by integrating technology that provides information on energy usage to low-income households. Advanced metering, in home displays, energy efficiency coaching, and providing usage information have all been successful strategies (Donovan et al., 2014).

5.4 DATA ANALYTICS

Finding: New publicly available data and tools on low-income energy consumption, are expanding. Nevertheless, more needs to be done to use these at a high spatial and temporal resolution to fine-tune program targeting and design.

New approaches have allowed for visibility into energy affordability and the socio-demographics of households. Data analytics and new digital tools such as the NREL Solar for All[67], and NREL ResStock[68] can help explain the relationship between energy affordability and socio-economic indicators to better understand the key factors that would drive changes in energy consumption. These techniques can be instrumental in estimating patterns of consumption and identifying areas where most of the savings can be made at the household levels (Hosgoer and Fischbeck, 2015; Long et al., 2018; Nahmens, Joukar, and Cantrell, 2015; Porse et al., 2016; Reina and Kontokosta, 2017; Wierzba et al., 2011; Zhang et al., 2018).

Jafary and Shephard (2018) use data from appliance usage to characterize consumption patterns of households across different building types. More high-quality data and techniques for analysis can also be useful in estimating the effect of the changing nature and composition of energy consumers. For example, Johnson et al (2017) use data from the PJM (a regional transmission organization) markets to estimate the effect of high solar PV adoption on cross-rate class subsidization and distribution of energy burden. Further, collecting and providing data can facilitate innovative approaches to analysis. It can help estimate the level and severity of the problem (Berry et al., 2018); it can be used to test the effectiveness of different low-income programs and project designs (Hoffman, 2017); to develop databases that predict deployment of new technology such as solar panels (Yu et al., 2018; Gupta et al., 2018b); further, data can be useful to draw more concrete results for utilities in order to target consumers who would gain from programs such as LIHEAP (O'Dwyer, 2017).

Understanding the impacts of low-income energy programs and policies can also be enhanced with data analytics. For example, the Greenlink Group has used mapping sciences to help visualize the relationship between household energy burdens at the county level and utility evictions in the State of Virginia (Figure 5.1).

Integrating new technology for collecting, generating and analyzing data can contribute to improved data analytics (Donovan et al., 2014; O'Dwyer, 2017). Machine learning techniques (Zhang et al., 2018) and agent-based modeling (Zhang et al., 2016) are promising approaches. With high-resolution data, investments in demand-side management can be designed to potentially displace the more expensive options of generation and grid investments (Reames, 2016; Khan and Duffy, 2018). All income groups would benefit from a shift from supply- to demand-side energy utility company investments enabled by data analytics. However, in many regions, such data are not available. The first step in making better data analytics possible will therefore be collecting, analyzing, and visualizing more spatially and temporally high-resolution data to better inform low-income energy programs (Reames, 2016).

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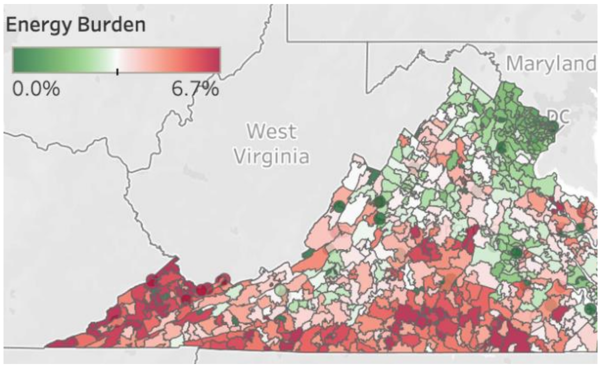
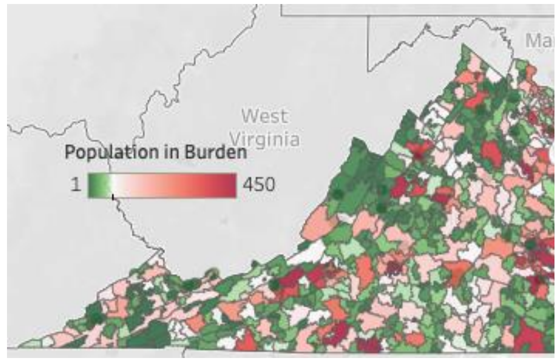
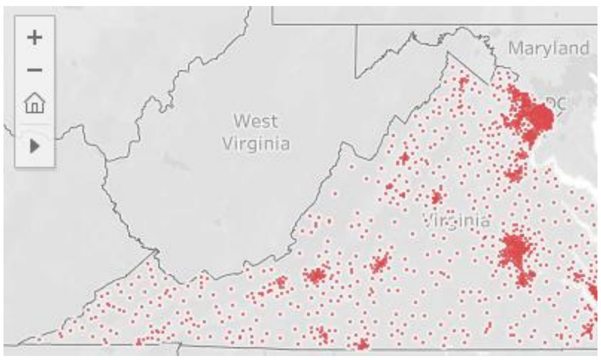
[67] https://maps.nrel.gov/solar-for-all/?aL=6m-d90%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=38.870832155646326%2C-98.34521484375001&tour=splash&zL=5
[68] https://www.osti.gov/biblio/1436972



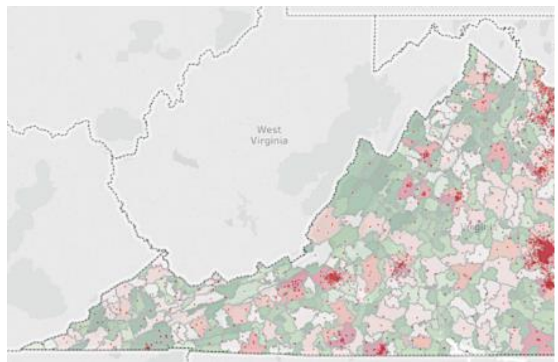
Electricity Burden (Median)



Electricity Burden (Population)



Incidents of Evictions



Electricity Burden and Evictions

Figure 5.1 Data analytics of energy burden and evictions across zip codes in Virginia[69]

5.5 ADVANCED INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

Finding: Information and communication technologies including smart thermostats and information feedback support low-cost behavioral approaches to improving energy efficiency, but they tend not to be incorporated into low-income energy programs.

Digital, market-based programs are being used to educate, incentivize, and "nudge" consumers to purchase energy-efficient products (Niederberger, 2018). Adopting behavioral strategies supported by technology and data to target online marketing for greatest impact can scale participation and improve the cost-effectiveness of residential programs to reduce energy burdens. Digital platforms and smart meter data are being deployed to reach households with high energy burdens (Sovacool et al., 2017). Energy burdens could be reduced if low-income tenants had a more expansive knowledge of how best to conserve energy, and ICT can help achieve this greater energy literacy. However, low-income households often lack Internet access – a "digital divide" exists. At best, they are unable to use such platforms or at worst, could be harmed by such business models.

When low-income respondents were asked how they would like to receive daily account information from their local utility, e-mailing was the dominant response, representing 45% of the households. Text messaging was viewed as the preferred information mechanism by 15%,

[69] https://www.thegreenlinkgroup.com/energy-equity

and the use of a mobile app by 12% of respondents (Table 5.1). Consistent with the digital divide, elderly and lower-income households are less likely to prefer the use of mobile apps (Treadway, 2018).

Table 5.1. Favorite way to receive daily account information from local electric utility
(Source of data: Treadway, 2018)

		Age		**Household Income**	
	Total	**18-54**	**55+**	**< $25K**	**$25K to $49**
Total Respondents with HH Income Less than $50,000	**(534)**	**(364)**	**(170)**	**(232)**	**(302)**
	%	%	%	%	%
Email	45	42	53*	41	48*
Text message	15	16	12	19*	12
Mobile app notification	12	15*	4	8	15*
More than one channel (phone, text message, email or app)	10	11	10	10	11
Recorded phone call	4	4	5	6*	3
Don’t know/no opinion	13	12	17	16	12

Q. B18: If you elected to receive daily account from your local electric utility, how would you receive it? Please choose your top choice. *Indicates figure is significantly higher than other sub-group at a 95% confidence level. The Russell Omnibus was conducted via the Internet among 1,092 adults 18 years of age or older from October 21-24, 2016.

One way for households to easily access and recognize their energy consumption is through the use of smart meters and smart thermostats. Smart meters enable a wireless two-way communication with the utility company (Brown, Zhou, and Ahmadi, 2018). These smart meters allow the utility companies to track peak demand times and usage. Nest thermostats are WiFi enabled and can be controlled by computers and cell phones. They display the current energy consumption of the home and have sensors for temperature, humidity, and motion. The Nest thermostat learns the user’s behavior, guarantees that no energy is wasted if no one is home, and helps manage usage during peak and off-peak times to help low-income households lower their total energy bill. Nest thermostats can be expensive at $250 before installation, deterring many low-income households from purchasing the device. Georgia Power currently offers a $100 rebate on Nest thermostats, but for low-income households, $150 is still a large sum of their monthly income. Therefore, implementing a monthly payment plan, on top of the rebates as an incentive program, is more feasible for these families. A Nest thermostat, on average, saves a household $140 per year, hence the price per month that they will pay for the Nest thermostat would be equivalent to the monthly savings made through their electric bill.[70]

“Peer-to-peer electricity” sharing could create a more affordable marketplace for electricity. In this marketplace, the people who can afford power generating sources such as solar panels can

[70] Nest Thermostat Real Savings. (n.d.). Retrieved April 22, 2018, from https://nest.com/thermostats/real-savings/

sell electricity to people who are unable to afford generating sources or who might have access to electricity but require more electricity at certain times (Inam et al., 2015). While this concept appears to not be operational in the U.S., it is beginning to enter markets in the Netherlands and Australia.[71]

5.6 GRID RESILIENCY

Electric and natural gas service disruptions due to extreme weather events and other hazards have brought increasing attention to, and study of, the resiliency benefits of energy system resources. In that vein, study of low-income energy efficiency and renewable programs, community-level microgrid infrastructure projects, and programs that may facilitate these local energy programs is an emerging area of study. While the definition of how-to value "resiliency" varies depending on program perspective and evaluation context, generally speaking, resiliency concepts refer to the flexibility of energy system resource(s), and the ability to "bounce back" and recover from system disruptions (natural and otherwise), as well as to adapt and improve over time.

Ribeiro et al. (2015) suggest that value and risks relating to resilience can be understood in terms of hazards, vulnerability, and capacity to cope.

$$\text{Risk} = \frac{\text{Hazards x Vulnerability}}{\text{Capacity to cope}}$$

Green Mountain Power has initiated a bold experiment to turn a low-income community into a virtual power plant. It is currently implementing the first community rooftop solar arrays for local low-income households in conjunction with battery storage that are helping customers move off the central grid for several hours every day.[72]

As utilities become more targeted in deploying energy efficiency to strengthen grid reliability by considering the time-varying and locational value of demand management, there is an opportunity to address challenges of economically distressed communities at the same time. This was achieved in a "non-wires alternatives" pilot program located in an economically depressed area, offering a learning experience for program design and implementation under such circumstances. Energy analytics played an important role in assessing the demand side management potential in the target area and to drive targeted and personalized customer interactions during implementation (Khan and Duffy, 2018).

[71] https://vandebron.nl/about; https://arena.gov.au/assets/2017/10/Final-Report-MHC-AGL-IBM-P2P-DLT.pdf
[72] New York Times, Utility helps wean Vermonters from the electric grid, https://www.nytimes.com/2017/07/29/business/energy-environment/vermont-green-mountain-power-grid.html

6. CONCLUSIONS

In the midst of a rapidly transforming energy system, this paper reviews the literature to assess how low-income energy burdens are changing, what policies and programs are impacting them, and what opportunities hold promise for progress in the future. Our literature review uses an energy equity lens to focus on procedural, distributional, and intergenerational issues related to low-income energy burdens.

Our literature review is complicated by several methodological challenges:

- Variable and inconsistent definitions and metrics are used to describe the energy consumption patterns of low-income households.
- The extent and nature of energy burden, and the estimated impact and value of solutions, depend upon the metrics used.
- There is limited publicly available data on low-income energy consumption, particularly at high spatial and temporal resolution, which constrains the ability of data analytics to fine-tune program targeting and design by federal, state, and local agencies, communities and NGOs, and utility companies.

The last decade has produced a large and expanding literature on low-income energy burden. Several broad conclusions are derived from that literature, which have equity implications.

- Energy burden is higher among low-income households than other income groups.
- The average energy burden of low-income households is not declining, and it continues to be high in particular geographies and socio-economic groups.
- Many policies and programs that promote energy efficiency and renewable energy technologies (e.g., rooftop solar PV and home battery systems) are largely inaccessible to low-income households, although several states have recently launched major low-income solar programs.
- The share of utility residential energy-efficiency funding that supports low-income households is lower than the percent of residential utility customers who are low-income.

The literature also documents a number of new approaches to the design and implementation of low-income energy programs and policies that appear to offer opportunities to amplify their success.

6.1 IMPROVING ENERGY EQUITY THROUGH PROGRAM DESIGN AND IMPLEMENTATION

A majority of low-income energy program funding focuses on short-term fixes to energy insecurity and not long-term solutions to reduce energy burden.

- Funding for temporary assistance (e.g., for bill payments) dwarfs funding for more enduring assistance (e.g., weatherization), though both serve a critical need and benefit from being linked.
- Funding for low-income energy programs peaked as a result of ARRA; it has returned to levels above the pre-ARRA funding, reflecting modest increases in weatherization funding and more substantial increases in low-income solar programs.

A number of submarkets and socio-demographic groups tend to be underserved by current low-income energy programs. Programs like WAP serve both to reduce energy burden and to improve the low-income housing stock across the country by making it more energy-efficient, comfortable, and healthier. Because many low-income energy programs serve homeowners, they also mainly serve white households (a distributive justice concern). Eliminating barriers to serving rental properties could drastically reduce energy burden and insecurity for households of color while reducing health and other racial disparities. This would benefit from additional research on the nature and role of landlords and property owners, which was found to be a notable gap in our review of stakeholders covered in the literature.

- The multifamily low-income market has been difficult to reach with traditional energy-efficiency programs due partly to misalignment of incentives.
- The opportunity to address the high energy burden of low-income households occupying manufactured and mobile homes has received limited analysis and policy focus.
- Low-income households in rural communities often spend as much as a quarter of their income on energy due partly to their low-density geography; assistance from local community programs and organizations are particularly critical to success in these markets.

Several promising technology approaches are not generally well integrated into low-income energy programs.

- Rooftop and community solar systems are now cost effective in many states as the result of declining costs and their involvement in low-income energy programs is beginning to take hold in some states.
- Health and safety upgrades are not components of most utility low-income energy-efficiency programs, and they are not fully integrated into the cost-benefit calculations of the WAP or state low-income energy programs.
- Information and communication technologies including smart thermostats and information feedback support low-cost behavioral approaches to improving energy efficiency; while they tend not to be incorporated into low-income energy programs, their presence in these programs is increasing.
- Electric vehicles and other approaches to affordable transportation have played limited roles in federal, state, local, and utility low-income energy programs to date.

Policies can be designed to address these gaps.

- States are using minimum requirements and adders to cost-effectiveness tests to promote greater investment in low-income energy programs.
- New program designs can align incentives more effectively for building owners and tenants.
- Strong community engagement and effective building owner and property manager partnerships can help reach multifamily markets.
- Active community involvement can expand participation rates and enhance the success of low-income energy programs.

6.2 SCALING IMPACTS WITH LEVERAGING, PARTNERSHIPS, AND PROGRAM INTEGRATION

Scalable approaches to reduce low-income energy burden require linking programs and policies to tackle the complex web of causes and impacts that households face, who have limited resources to pay energy bills. Two distinct opportunities exist: inter-agency cooperation and integrated technology-policy approaches.

Inter-agency partnerships offer greater resources and leverage, particularly if they span multiple scales (national, regional, state, and community) and multiple agencies with missions that touch on low-income energy burden. Evidence of the potential payback to engagement of non-energy agencies is provided by the significant non-energy benefits that are created by low-income energy programs.

- At least four parallel federal programs have missions related to low-income energy burdens, with varying levels of inter-agency coordination at the federal, state, and local levels.
- The savings-to-investment ratio of WAP is favorable based on the value of its energy savings alone.
- Without monetizing non-energy benefits, low-income energy-efficiency programs operated by electric and gas utilities cost more to implement per household and are less cost-effective than utility-operated energy-efficiency programs serving higher income groups. Low-income energy programs ensure low-income households can benefit from ratepayer funding that they help pay for but would otherwise not benefit from.
- The value of the non-energy benefits of WAP and other low-income energy programs are significant.

Integrated technology-policy approaches offer opportunities to leverage a broader array of rapidly advancing technologies (advanced efficiency, solar PV, storage assets, smart meters, and more). Expanding implementation of these technologies can be achieved with novel and integrated approaches to inclusive financing, philanthropic partnerships, energy assistance, and payment arrangements. More holistic approaches can maximize benefits and minimize costs.

- Expanding the technology scope of low-income energy-efficiency programs to include solar PV, smart meters, storage, and electric vehicles could significantly improve energy affordability for low-income households.
- Broadening finance and administrative options (e.g., on-bill tariff designs) can maximize benefits and minimize costs, if designed effectively.
- Public-private-philanthropic-partnerships and interagency coordination and leveraging can reduce energy costs for low-income households while also delivering non-energy benefits.

Both funding and execution will require finely meshed and interwoven delivery systems that engage all the stakeholders shown in Figure 1.1. A coordinated approach to home energy, health, safety, and housing that integrates programs across geographies could reduce low-income energy burden while delivering numerous other benefits to both current and future generations. As the U.S. transitions to a new energy economy, these solutions offer low-income households the opportunity to meet their energy service requirements more affordably.

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