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Participant outcomes in residential Pay As You Save® programs

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Acronyms and Abbreviations

ACS	American Community Survey
CDD	Cooling degree days
HDD	Heating degree days
HVAC	Heating, ventilation, and air conditioning
NPV	Net present value
OLS	Ordinary least squares
PAYS®	Pay As You Save®
PRISM	Princeton Scorekeeping Method
TMY3	Typical Meteorological Year version 3
USDA	United States Department of Agriculture

Executive Summary

In this technical report, we review the energy and financial outcomes for households participating in several programs based on successive versions of the Pay As You Save® (PAYS®) system. PAYS® programs offer non-debt financing for energy efficiency (and sometimes other technologies) in residential buildings[1] and collect repayment through a tariff attached to the home's utility meter. The monthly tariffed charge is designed to be offset by project savings; PAYS® projects require that over the course of a year the total tariffed charges will not exceed some fraction (generally 80% or 90%) of the expected bill savings estimated prior to the projects. We consider how participants' energy usage changed post-project, and how weather-normalized energy bill changes compare to tariffed charges.

We collected and analyzed project data from five PAYS® programs: the U-Save Advantage program at the Appalachian Electric Cooperative; the How$mart® KY program, available through several electric cooperatives in Kentucky; Midwest Energy's How$mart® program; the Ouachita HELP PAYS® program at the Ouachita Electric Cooperative; and the Upgrade to $ave program at the Roanoke Electric Cooperative. By matching participant locational data to demographic data from the American Community Survey, we find that the five programs we study generally serve communities with levels of income and education below the national average and unemployment rates above the national average.

We also analyzed the electricity and gas usage impacts of one program (Midwest Energy's) using weather-normalized methods applied to metered energy consumption data. We show that most participants in Midwest Energy's program reduce annual electricity and gas consumption, averaging 15% and 26% reductions respectively. Changes in energy consumption calculated using this method represent a combination of project effects and changes in occupant behavior. The energy usage reductions we calculate *ex post* (using usage data measured after the project) are about 83% of the energy savings estimated by the program *ex ante* (prior to the project). Both our energy usage results and our savings realization rates results are similar to existing analyses of PAYS® programs in North Carolina, Arkansas, and Tennessee. Table ES-1 summarizes average project usage impacts from our analysis.

[1] While this report focuses on the most common use of the system (programs serving residential customers), the PAYS® system can serve all customer classes. The oldest continuous PAYS program, run first by Public Service of New Hampshire and now its successor Eversource, was designed to serve municipal customers. Programs in Kansas and Arkansas also provided program services and upgrades to non-residential customers (schools and commercial buildings).

Table ES-1. Average annual household energy usage impacts for Midwest Energy projects

Fuel	*Ex ante* estimated annual household savings	*Ex post* calculated annual household usage reductions	*Ex post* percent usage reduction	95% confidence interval	Realization rate
Electricity	2,473 kWh	2,056 kWh	15.2%	+/- 1.4%	83.1%
Gas	265.9 therms	219.8 therms	26.2%	+/- 3.5%	82.7%

Based on our analysis, about half of participating Midwest households generate sufficient annual energy cost savings to cover their total monthly tariffed charges in a normal weather year. We show that energy price trajectories (electricity and gas prices, in the case of the Midwest Energy program participants) are an important determinant of these net bill outcomes. We calculated participant cost impacts using illustrative high and low energy prices scenarios for each fuel, based on a combination of observed prices during the study period and escalation rates used in Midwest's project cost calculations. In low energy price scenarios, the installed measures yield lower cost savings and the average household has higher annual costs (including the tariffed charges) than it would have absent the project. High energy price scenarios yield greater cost savings and the average household sees lower annual net costs than it would have absent the project. Various factors, including changes in occupant behavior, program error, causes independent of the participant or program, or some combination thereof may explain lower-than-expected energy and cost reductions in some projects.

We also find that energy cost savings are higher in winter and summer, as shown in Figure ES-1. This is unsurprising given that the studied PAYS® projects predominantly affect energy usage for space heating and space cooling. Since the participating households have higher energy costs in winter and summer, the PAYS® projects have the effect of smoothing monthly energy costs to some extent, which may be helpful for households managing monthly expenses.

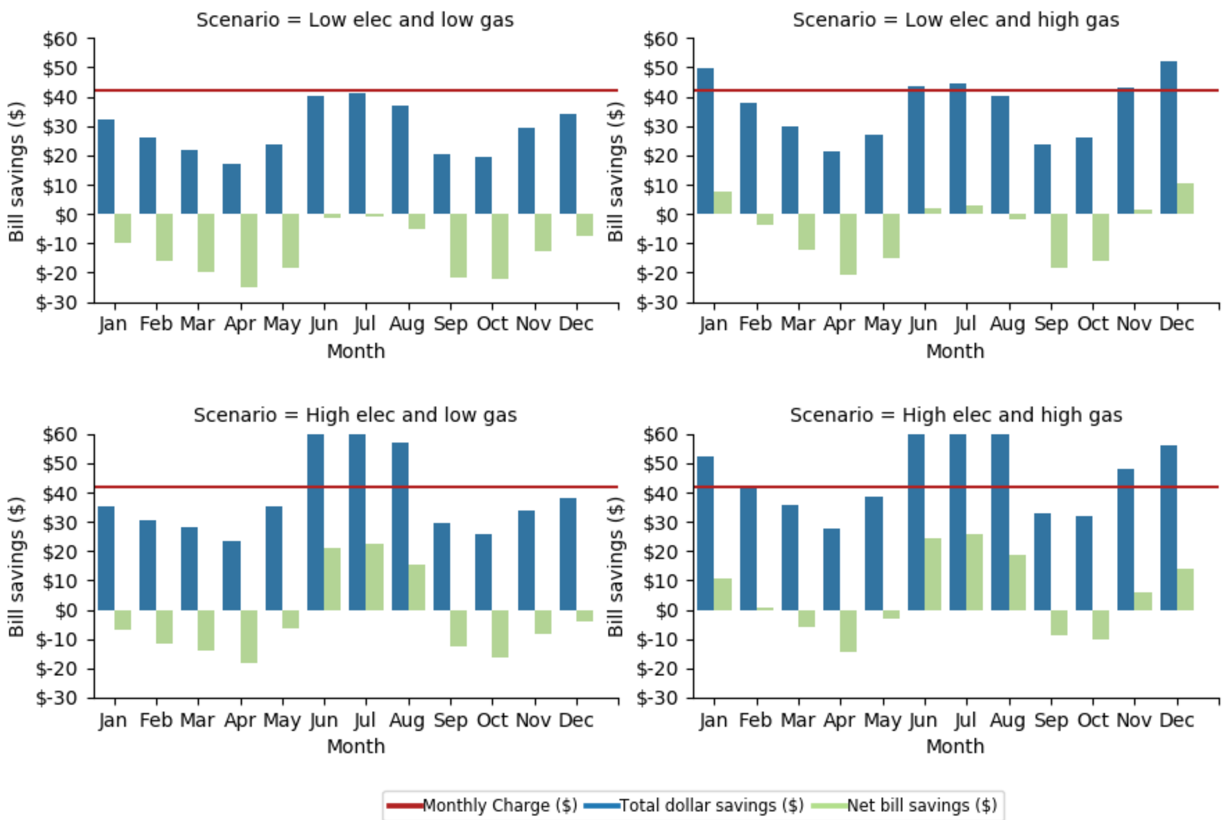

Figure ES-1. Monthly cash flows for Midwest projects by price scenario

In our view, the energy and cost impacts of the Midwest Energy projects, and of the other PAYS® programs available in the literature, are within reasonable expectations. Over time, PAYS® participants pay the full cost of the measures installed, not merely the incremental cost of more efficient measures. Given the inherent variability in household energy consumption and cost, volatility in energy prices, and the influence of non-project factors, we would not expect that every participating household's net energy costs would go down. PAYS® programs include a number of features that promote participant cost savings, including: requiring *ex ante* estimated savings to exceed the tariffed charges; requiring the tariff term to be less than the effective useful life of the project; and requiring program administrators to take remedial action if projects do not perform as expected. We expect that these program features reduce the share of participants who see their costs rise.

1. Introduction

Many homes in the United States use energy inefficiently. Upgrades to these homes can in some cases pay for themselves over time through reduced energy costs while generating public benefits via reduced emissions of greenhouse gases and other pollutants. However, these upgrades are often challenging for households to finance. Many households, especially those in disadvantaged communities, do not have sufficient funds on hand to pay the up-front cost of energy efficiency upgrades. Federal and utility weatherization programs provide free or greatly reduced-cost assistance to a subset of income-qualified households, but are not sufficiently resourced to reach all such homes and do not help the many households that do not qualify but still do not have sufficient cash on hand to pay for upgrades. Unless homeowners can draw equity from their homes—which carries fixed costs that energy efficiency projects often cannot cover—capital for these upgrades is often only available at high interest rates. Credit-challenged households may not be able to access capital to fund these projects at all.

The need to overcome these "first cost" barriers has motivated a number of different programs that seek to make capital available for energy efficiency improvements.[2] Pay As You Save® (PAYS®) programs[3] are one of these program types. PAYS® programs are part of a broader category of programs known as inclusive utility investment programs.[4]

PAYS® programs have attracted considerable attention as a vehicle to overcome first cost barriers, especially in credit-challenged households and households in disadvantaged communities. As described more fully below, these programs enable participating households to receive energy efficiency upgrades without taking on debt and without needing to meet credit score or debt-to-income thresholds to qualify. By requiring estimated energy bill savings to exceed the tariffed charge used to recover project costs, the programs seek to ensure that their participants' total annual expenses go down and therefore that program participation does not impose financial strain.

To date, PAYS® programs have been relatively limited in scale.[5] However, a number of programs have recently launched or are under development at larger investor-owned utilities, demonstrating the high level of interest in the model. These efforts include programs at all investor-owned utilities in the state of Missouri (Ferguson et al. 2022). Since PAYS® programs leverage utility capital and recover costs through a tariff, they require approval from either state utility commissions or oversight boards,

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[2] For an overview, see Leventis et al. 2016.

[3] PAYS® is a trademarked term that refers to programs that meet specific requirements. The Energy Efficiency Institute, Inc. (EEI) holds the trademark. EEI specifies essential elements of PAYS® programs on its website: http://www.eeivt.com/pays-essential-elements-minimum-program-requirements-2/

[4] See https://www.energystar.gov/products/inclusive_utility_investment for more on inclusive utility investment

[5] Per Clean Energy Works, PAYS®-style programs have supported 5894 total projects as of June 7, 2022. See https://icc.illinois.gov/api/web-management/documents/downloads/public/informal-processes/equitable-energy-upgrade-plan/Clean%20Energy%20Works%20Presentation%20PAYS%20Programs%20in%20the%20US.pdf

depending on the type of utility sponsoring the program and the state in which the utility operates.[6] State legislation is not necessary to start a PAYS® program, though it can initiate commission proceedings to establish a program.[7]

In this study, we leverage project information from five PAYS® programs and energy usage data from one PAYS® program. We also draw on existing studies of PAYS® projects. Using these sources, we:

- Review key design elements of PAYS® programs
- Delineate the demographic and socioeconomic characteristics of participating households using place-based Census data
- Provide detailed information on PAYS®-financed projects, including measures financed, tariff amounts, and participant copays
- Assess the energy usage reductions, utility bill impacts, and overall financial outcomes realized by households participating in one PAYS® program.

This analysis will enable interested jurisdictions to make a better-informed appraisal of PAYS® as a potential program solution for consumers by helping set expectations for the outcomes such programs might achieve—though future program designs and outcomes may differ from the programs we study here. We also identify considerations for program design elements that might better enable PAYS® at scale.

PAYS® programs are notable for the significant safeguards they place on participant outcomes, as discussed in detail in Section 2. In part through these same safeguards, the programs also attempt to broaden access to capital relative to energy efficiency loan programs that use conventional borrower eligibility thresholds (most often credit score and debt-to-income thresholds) to approve participants. To the extent that these programs reach economically disadvantaged households—an explicit program goal in some cases—the financial impact of projects on household expenses is a central concern. As such, we explore in detail (as our data and the existing literature permit) the energy and financial outcomes for PAYS® participants, and consider the inherent tradeoff between broadening project eligibility and delivering cost savings to all participants.

1.1 What is PAYS®?

While specific program designs vary, PAYS® programs share a number of central features. When a household chooses to participate in a PAYS® program offered by its utility, the utility funds some or all

[6] State utility commissions have authority over investor-owned utilities. In some states, utility commissions also oversee rate-setting for municipal and cooperative utilities, and commission approval would be required for a program run by one of these utilities. In other states, utility-specific oversight boards have authority over municipal and cooperative utilities, and these boards would approve a program.

[7] Recent legislation in Illinois, for example. directed the Illinois Commerce Commission to require investor-owned utilities to establish PAYS™-style programs. For details, see https://www.icc.illinois.gov/informal-processes/Equitable-Energy-Upgrade-Plan

of the capital cost of an energy project[8] as an up-front investment. Typical measures installed via PAYS® include space heating and/or cooling equipment, air and duct sealing, insulation, and in some cases lighting. The utility recovers its up-front costs over time through a fixed charge[9] for a specified term (often 10-15 years), approved in a tariff and attached to the location and its electric meter.[10] This tariffed charge is placed on the program participant's electricity bill and treated in similar fashion to any other bill charge until the utility has recouped its cost at the end of the term. Because the tariffed charge is attached to the metered location, not the resident, a new owner or renter who moves into a participating location before the end of the tariff's term simply assumes the charge as part of their utility bill. During the term of the tariff, the utility owns the newly-installed measures. At the end of the tariff's term, ownership of the upgrades transfers to the participating household. The term of the tariff cannot exceed some percentage (e.g., 80%) of the expected useful life of the installed improvements, thus attempting to ensure that the funded projects continue to deliver savings over the life of the tariff to offset the tariffed charge.

Unlike a loan recipient, a PAYS® participant does not take on debt when enrolling. Approval for PAYS® projects is generally based only on the expected cost and energy savings of the project, rather than participant's credit score and debt-to-income ratio.[11] This approach is a key component of the "inclusivity" of PAYS® programs: any project that can cover its costs can be financed, regardless of the credit and financial characteristics of the participating household. PAYS® programs also reduce or eliminate landlord disincentives to invest in energy efficiency because the tenants pay for most or all of the improvements to the property over time through the tariffed charges on their energy bill. The PAYS® approach resembles "project finance" approaches used for large capital investments that generate revenue (such as power plants), whereby projects are primarily financed based on the cash flows they generate, not the balance sheets of the companies that own them.

Given the PAYS® approach to project eligibility, the cash flow test plays a critical role. The cash flow test requires that the tariffed charge must not exceed some percentage of expected average monthly cost savings generated by the project. This percentage varies by program, from 75% to 90% in the five programs we study. If a household wishes to pursue a project that does not meet this cash flow test, it can make a copayment to reduce the utility's investment amount to the level where the project will meet the cash flow test.

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[8] PAYS® programs also fund water efficiency upgrades. The programs we review here fund mostly energy efficiency projects (Ouachita's program has supported a small number of solar PV projects).

[9] A tariff defines the way a utility or other energy provider charges a customer for services provided.

[10] 'Attachment to the meter' means that energy efficiency project investment is repaid through charges collected only from the meter at the site of the improved property.

[11] Some PAYS® programs consider the potential participant's utility bill payment history as a criterion for eligibility. Many PAYS® advocates feel this criterion cuts against the program goal of inclusivity. The Energy Efficiency Institute's current program guidance does not permit using bill payment history as an eligibility criterion. The two How$mart® programs we study - Midwest Energy and Kentucky - consider utility bill payment history for program eligibility, while the other three programs do not. At the time the Midwest Energy and Kentucky programs launched, program guidance did not prohibit consideration of utility bill payment history. The Roanoke program used bill payment history to target member-owners with high energy usage and missed payments, but did not use it to screen out potential participants.

During the term of the tariff, the sponsoring utility and program administrator are responsible for making sure the upgrades are working properly, and must respond to any performance concerns expressed by participants. The PAYS® program will suspend, reduce, or eliminate payments if the measures are not performing. For more details on PAYS® program characteristics, see Hummel and Lachman (2018) and Bickel, Ferguson, and Kauffman (2020).

2. PAYS® participants and projects

In this section, we characterize PAYS® program participants and projects using detailed project information generously furnished by five PAYS® programs.[12] Table 1 summarizes the names, associated utilities, and key features of these programs.

Table 1. Key features of studied PAYS® programs

Program	Participating utilities	Program administrator	Program years of operation	Total number of projects[13]	Share of *ex ante* estimated savings available for cost recovery
U-Save Advantage	Appalachian Electric Cooperative	EEtility	2019 - 2021	75	80%
How$mart® KY	Fleming-Mason Energy, Licking Valley Rural Electric Cooperative, Jackson Energy Cooperative, Big Sandy RECC, Farmers RECC, Grayson Rural Electric	Mountain Association	2011 - present	326	90%
Midwest Energy How$mart®	Midwest Energy	Midwest Energy	2007 - present	2475	90%
Ouachita HELP PAYS®	Ouachita Electric Cooperative Corporation	EEtility	2016 - present	409	80%
Upgrade to $ave	Roanoke Electric Cooperative	EEtility	2014 - present	654	75%/80%[14]

Each program dataset included project locations, costs, measures installed, and calculated savings

[12] These are the five programs that had executed a substantial number of energy-focused residential projects and were active at the time we began this study. Generously, all five agreed to provide project data to Berkeley Lab.

[13] Total project counts for U-SAVE Advantage, Ouachita HELP, and Upgrade to $ave are from Liberty Homes and the Energy Efficiency Institute's 2021 PAYS® Status Update: https://www.eeivt.com/wp-content/uploads/2021/12/2021-PAYS-Status-Update_12.30.21rev.pdf. Project counts from How$mart® KY and Midwest Energy How$mart® are from data reported to us by the programs themselves.

[14] Roanoke's program started out allowing tariffed charges up to 75% of average *ex ante* estimated monthly savings, but later moved to 80%.

estimates based on site-specific analyses. Some programs provided additional data on the type of building where the project took place and whether it was owner-occupied or rented. For Ouachita, we received data on program homes that used electric space heating after the PAYS® project—either because the home already had electric space conditioning or because it switched from another space heating fuel to electricity. We did not receive data on projects using other space heating fuels such as propane. For Roanoke, the data only covered projects performed by their current program administrator, EEtility, which began administering the program in 2017.

2.1 Participant demographics

The project data we received did not include any household-level demographic data on program participants, but did include project zip codes. We characterize the demographics of participants' neighborhoods by matching data from the 2019 American Community Survey (ACS) to project zip codes. We select a range of demographic factors (race, education, income, and unemployment) as well as the built environment (single family vs mobile home). For each program, we weight zip code-level ACS data by the number of projects in each zip code before aggregating to the program level. Table 2 summarizes these participant-weighted values for each of the five programs.

Table 2. PAYS® participant demographics by program

Program	White-identifying population	Black-identifying population	Has bachelor's degree or higher	Unemployment rate	Average household income	Single family homes[15]	Multi-family homes	Mobile homes[16]
Appalachian	94.8%	3.7%	15.9%	6.2%	$62,145	69.8%	10.3%	19.8%
Kentucky	96.9%	3.1%	14.9%	7.8%	$51,633	66.4%	10.8%	22.8%
Midwest	95.1%	2.7%	35.0%	2.9%	$73,285	73.1%	22.9%	4.0%
Ouachita	60.1%	39.8%	14.9%	8.1%	$51,283	74.4%	13.4%	12.2%
Roanoke	46.1%	52.0%	15.3%	7.9%	$54,047	65.5%	10.0%	24.6%
National	75.3%	14.0%	32.1%	5.3%	$88,607	67.5%	26.3%	6.2%

We find that the participants typically live in areas with household incomes and levels of higher education well below the national average and unemployment rates well above the national average. Midwest Energy program participants are the exception, as they live in zip codes with incomes closer to, though still below, the national average; levels of higher education slightly above the national average; and unemployment rates well below the national average. The programs in Kentucky, Kansas and Tennessee serve zip codes that are almost exclusively white. In contrast, Ouachita participants live in relatively mixed white and Black areas and Roanoke participants live in majority Black areas. Shares

[15] We include both attached and detached single family homes in this category
[16] We include mobile homes and doublewides in this category

of single-family housing in participant zip codes are slightly higher than the national average. Apart from the Midwest program, shares of mobile homes in participant zip codes are much higher than the national average.

We considered whether the participant-weighted results are reflective of each utility's service territory by weighting zip code-level demographics by zip code-level population.[17] We did not find large differences between the participant and service territory demographics, which suggests that the programs are not disproportionately operating in particular areas of their service territories.

2.2 Project characteristics

2.2.1 Buildings

Three of the programs in our study—Appalachian U-Save Advantage, Roanoke Upgrade to $ave, and Ouachita HELP PAYS®—provided information on the type of building in which each project took place. We summarize this data in Table 3. 9.5% of Appalachian's projects are in mobile homes, less than the 20% overall share of mobile homes in Appalachian participants' zip codes. On the other hand, one third of Roanoke participants live in manufactured housing, somewhat higher than the one quarter of manufactured homes in Roanoke participants' zip codes. Ouachita is unique with regard to apartments: the program served 81 apartments (nearly half the reported projects), all located in a handful of apartment buildings.

Table 3. Project building types by program

Program	Stick-built single family[18]	Apartment	Mobile home/doublewide
Appalachian	90.5%	0.0%	9.5%
Ouachita	49.7%	44.7%	5.6%
Roanoke	66.0%	0.0%	34.0%

2.2.2 Measures

In Table 4, we characterize projects by their mix of energy efficiency measures. Each value represents the share of projects in a program that include a particular measure type. Across the programs, the projects consist of heating, ventilation, and air conditioning (HVAC) measures and weatherization (insulation and air sealing). Most projects in each program include HVAC measures such as heat pumps. LED lighting is very common in the Appalachian, Ouachita, and Roanoke PAYS® programs, but not in the Midwest and Kentucky How$mart® programs.

[17] We do not have a comprehensive list of zip codes served by each program, so here we include only zip codes that hosted at least one project in our data.

[18] A stick-built home is one that is constructed from wood on site, as opposed to manufactured elsewhere (as mobile homes are).

Table 4. Share of projects that include each measure category by program

Program	HVAC	Insulation	Air &/or duct sealing	LED lighting
Appalachian	80.0%	48.0%	73.3%	86.7%
Kentucky[19]	92.0%	62.9%	84.7%	3.4%
Midwest	96.8%	43.1%	15.1%	0%
Ouachita	92.7%	unknown[20]	93.9%	95.0%
Roanoke	90.1%	32.1%	85.8%	90.1%

In Table 5, we summarize average project financial characteristics for projects overall and for projects with and without participant copayments (copays). The total participant cost (tariffed amount plus copay) for PAYS® projects varies somewhat by program due to differences in copay amounts, cost of capital, and utility cost recovery terms. Because of differences in average copays across programs, the tariffed amount generally exhibits less variation than the total participant cost. It excludes any utility incentives[21] or participant payments that reduce the total project cost. Overall, tariffed charge amounts across the programs are quite similar, which is not surprising given that the programs, for the most part, installed similar measures.

The utilities that sponsor these programs all accessed various forms of low-cost capital to invest in these projects, such as loans from the U.S. Department of Agriculture (USDA) or the National Rural Utilities Cooperative Finance Corporation, or funds from state energy or housing programs. The utilities use tariff proceeds to repay these loans. Midwest Energy also uses some of its own capital to fund projects. Cost of capital for participants ranges between 2% and 3.6%.

Program average monthly payments are generally proportional to average principal amounts, though differences in tariff terms drive some differences. For example, Roanoke projects have an average principal amount similar to that in Midwest projects but have an average tariff term (113 months) that is almost five years shorter than the average term in Midwest (180 months). As a result, Roanoke projects have a higher average monthly tariffed charge than Midwest projects. For some programs the allowed term is limited: by the PAYS® tariff to 80% of the estimated useful life of the upgrades, or by USDA loan program restrictions when USDA is the capital provider. For example, Ouachita received a Rural Energy Savings Program loan from USDA in 2019 that restricts cost recovery to ten years and Roanoke received an Energy Efficiency Conservation Loan from USDA that restricts cost-recovery to 12 years in most cases.

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[19] Kentucky How$mart® also includes measures not included in the table. Water heating, windows and doors, and 'other' measures are in 1.5%, 4.6%, and 31% of projects.

[20] The project data we received from Ouachita do not indicate any homes with insulation upgrades; however, the program does include insulation and it's likely that this information is missing in the data.

[21] In our understanding, the utilities sponsoring these programs offer few or no incentives.

Table 5. Project financial characteristics (average values unless otherwise stated)

		Appalachian	Kentucky	Midwest	Ouachita	Roanoke
All projects	Cost of capital (annual)	2.0%	3.0%	3.2%	3.6%	3.0%
	Tariff term (months)	135.5	145.7	179.9	135.2	113.1
	Monthly tariffed charge ($)	$48.39	$42.78	$41.49	$56.44	$56.20
	Ex ante expected monthly savings ($)	$62.44	$52.64[22]	$50.24	$74.11	$78.19
	Total participant cost (tariffed amount plus copay)	$7704	$7323	$9659	$8247	$6975
	Share of projects with a copay	52.60%	47.50%	73.60%	31.30%	14.60%
	Total tariffed amount (including cost of capital)	$6269	$6418	$6391	$7525	$6469
Projects without copay	Total tariffed amount (including cost of capital)	$6932	$6205	$8145	$8067	$8036
Projects with copay	Average/ median copay ($)	$2027/ $2008	$2116/ $1250	$2687/ $1882	$1765/ $1432	$1890/ $1725
	Total participant cost (tariffed amount plus copay)	$8960	$8322	$10832	$9832	$9925

The average monthly dollar savings estimated *ex ante* by the programs all exceed the monthly payments. This result is consistent with program rules that require payments not to exceed a certain percentage of *ex ante* estimated monthly savings. On average, payments as a share of expected savings are all about two to five percentage points below these thresholds. A notable exception is the Kentucky program, which permits a monthly tariffed charge up to 90% of expected savings while in practice the charge averages only 76% of expected savings. Expected savings vary widely within and between programs, reflecting different baseline conditions of project households, different program targeting practices,[23] different measures and projects that qualify under each program's eligibility rules,[24] climate, energy prices, and differences in savings estimation methodologies.

2.2.2.1 Copays

Cost-effectiveness of an energy efficiency upgrade is determined by several factors: the energy savings potential of the installed measures; electricity, gas, and delivered fuel prices; the cost of capital; the

[22] Note: In calculating the expected monthly savings, we removed 36 projects for which Kentucky did not include ex-ante gas savings in its reported estimate of project dollar savings. We also removed one project with a reported negative principal amount, which we interpreted as a data-entry error.

[23] For example, Roanoke began targeting high-usage member-owners partway through its program.

[24] For example, the Midwest program does not include LED lighting, a generally cost-effective measure, which may be one reason that copays are more frequent in that program.

allowed length of the utility cost recovery period; and the installation contractor's labor, materials, and equipment prices. Where one or more of these factors is unfavorable, expected savings may not be sufficient to cover the entire cost of the upgrades. PAYS® programs address this shortfall by allowing program participants to make a copayment that covers the difference between the total job cost and the amount covered by the utility investment plus any incentives. Some programs often make two offers: a no-copay weatherization-only upgrade offer and an offer that also includes a new HVAC system, which may include a copay. Other programs, like Midwest, do not always offer a no-cost option (though, of course, participation in any of these programs is optional).

Per Table 5, the frequency of copays varies substantially by program. 15% of Roanoke and 30% of Ouachita projects have copays while about half of Appalachian and How$mart® KY projects and nearly 75% of Midwest projects include copays. Among projects with copays, average copays for all programs fall between $1700 and $2700 while median copays fall between $1200 and $2100. In all programs, the average copay exceeds the median copay, which reflects the presence of some projects with large copays.

We performed regression analysis to determine what factors are associated with copays at the project level. We find statistically significant relationships at a 95% confidence interval between the types of measures in a project and both the frequency and size of copays (see Appendix A for full regression results). When controlling for program effects, projects with HVAC measures are 22% more likely to have a copay and projects with insulation are 8% more likely to have a copay. However, projects including air and/or duct sealing are 12% less likely to have a copay. Among projects with copays, the installation of an HVAC measure increases average copay amounts by about $1500 and the installation of insulation increases average copay amounts by about $400. These results suggest that measure mix is an important driver of copays: higher-cost HVAC and insulation measures more often require them, while air and duct sealing—often very cost-effective measures—reduce the need for them. We also find that copays are more likely in Midwest Energy relative to the other programs even when controlling for measure mix. Per Table 2, Midwest's member-owners[25] have the highest zip code-based income and may be more able to choose and pursue projects that require copays.

Figure 1 considers projects with copays in each program. We estimate what their monthly payments would have been had the copay cost been recovered through the tariff using reported project costs, copay amounts, tariff terms, and costs of capital. The green bars denote what monthly payments would have been without a copay, as a share of ex ante estimated dollar savings. The blue bars denote monthly payments as a share of estimated savings with the copay.

Among projects that include copays, we find that the copay is usually necessary to meet program cost tests. These projects are often not close to qualifying without the copay, as demonstrated by the distance between many of the green bars and the cost test thresholds. In contrast, with the copay (blue

[25] Rural electric cooperatives do not have customers, because they are coops all those who receive electricity services are "member-owners".

bars), the monthly payments as a share of expected savings are concentrated at the program-specific thresholds described in Table 1. In the case of EEtility-run programs, this clustering corresponds with program rules that stipulate that participants can only make copays necessary to reduce the project cost to the maximum amount supportable by estimated savings. Midwest, on the other hand, allows copays of any size, but (as the figure illustrates) few participants choose to make larger copays than are necessary to qualify the projects.

In each program, more than 85% of the projects with copays would not have qualified absent the copay. As such, availability of up-front incentives—such as those soon to be available under the federal Inflation Reduction Act—could cut down substantially on the frequency and amount of copays (see Section 5.2).

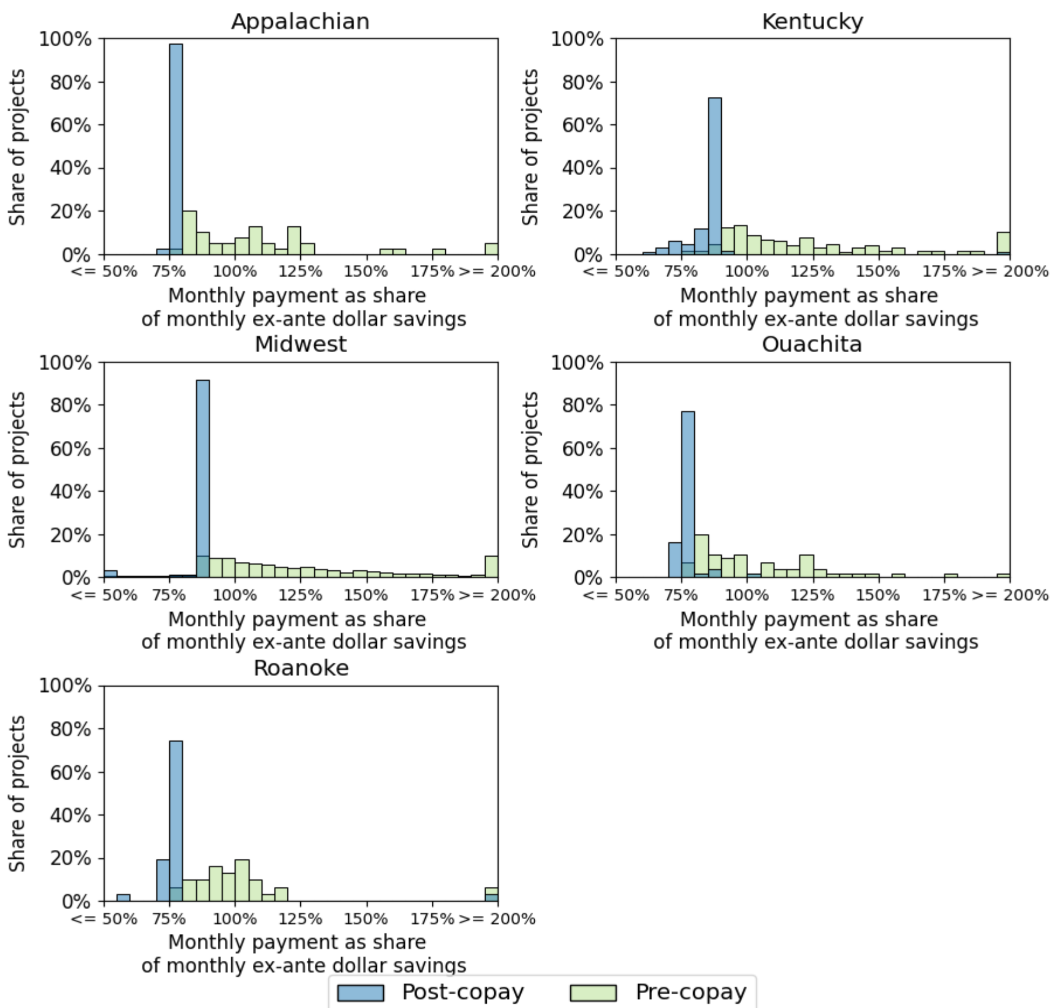

Figure 1. Monthly payments as a share of *ex ante* savings for project with copays, pre- and post- copay by program. In all programs, post-copay monthly payments cluster at the program's threshold share for copay amounts. A small number of projects exceed those thresholds in a few programs; we assume these are the result of errors in the data.

3. Data and methods

We estimated the energy usage impacts of Midwest Energy projects by comparing pre- and post-project usage and accounting for changes in weather. This weather normalization approach is common in assessments of energy efficiency programs, including existing analyses of the Roanoke and Ouachita programs (Kauffman 2021; Bickel, Ferguson, and Kauffman 2022; Bickel et al. 2022). By comparing usage before and after a project, this methodology is sensitive to actual measure installation and commissioning and captures behavioral responses to the installed equipment.

Weather-normalized usage estimates serve as a check on the *ex ante* estimates that underlie PAYS® project eligibility. However, weather-normalized estimates are based on whole-building energy usage, which may change after a PAYS® project for reasons unrelated to the energy efficiency project installed. If a PAYS® household also installed a swimming pool, for example, its overall energy usage could increase despite energy use reductions from more efficient heating and cooling equipment. An economic downturn, on the other hand, could suppress energy usage, giving the appearance of efficiency savings. Control groups of homes similar to project households can help account for the latter impact, and data on non-project changes could help account for the former, but we lack the data to conduct these analyses. As a result, it is not uncommon for an *ex post* estimate of project impacts to differ substantially from the *ex ante* estimate at the household level. This difference does not necessarily indicate that the *ex ante* estimate was inaccurate. If we make the reasonable assumption that non-project effects (e.g. pool installations) are not systematically correlated with project adoption, we can average out their impacts by aggregating the changes in usage from many projects.

3.1 Overview of Midwest Energy data

We received monthly electricity and gas usage data on 546 projects from Midwest Energy that took place between 2007 and 2017.[26] We received this usage data from the Midwest How$mart® program; we were not able to access the utility's general billing data records.

The electricity and gas data included 12 months of pre- and post-project usage. However, these data did not always immediately precede or follow the project end date. 71% of households' electricity and gas post-project usage begins within a year of a project's end date and 68% of households' electricity and gas pre-project usage data ended less than six months before a project's start date. The lag in post-project usage is a feature of the Midwest Energy How$mart® program's data collection procedures: the program pulls usage data on batches of recent projects at the same point in time. For example, post-project usage for a batch of projects that took place before May 2011 might cover the period May 2012 – April 2013.

[26] According to Midwest data, none of the projects in our sample included savings from delivered fuels such as propane or fuel oil.

Pre-project usage typically ended less than a year before project start dates. However, for 91% of projects the usage data we received was a monthly average of usage for the three years preceding a project. For example, reported pre-project usage data for May 2015 was often an average of usage in May 2013, May 2014, and May 2015. The program uses three-year averages to qualify projects so that pre-project usage would not be unduly influenced by some unusual one-time event. For our method it is generally preferable to have actual, not averaged, pre- and post-project data that bookend the project, so that usage patterns are similar throughout the study period and changes in usage are more likely to be associated with the project. The lag in post-project usage and the averaging of pre-project usage likely reduces the precision of our household-level estimates but should not introduce any bias.

3.2 Weather normalization

To weather normalize the pre- and post-project electricity and gas usage we use the Princeton Scorekeeping Method (PRISM) (Fels 1986), as implemented by the monthly CalTRACK methodology.[27] The weather normalization involves the following steps:

- Estimate how reported electricity and gas usage change with *observed* cooling and heating degree days respectively in the baseline (pre-project) period with linear regression
- Fit a second regression of electricity and gas usage on *observed* cooling and heating degree days in the reporting (post-project) period
- Estimate pre- and post-project usage in a '*normal weather year*' by running the baseline and reporting models developed in the first two steps on cooling and heating degree days derived from Typical Meteorological Year (TMY3) data (Wilcox and Marion 2008)
- For both electricity and gas, subtract the weather-normalized post-project usage from the weather-normalized baseline usage. This difference is the estimate of usage changes from the efficiency project.

For each household's electricity and gas usage, we select the model with the best fit (highest adjusted R^2) from a range of balance points for heating and cooling degree days, respectively. We also consider a model that does not include heating degree day (HDD) and cooling degree day (CDD terms). When this model fits best, this indicates that a household's electricity or gas usage is not weather-sensitive.[28] For projects whose pre-project usage data consists of three-year averages, we employed the average heating and cooling degree days in each month over that three-year period.[29] Deason et al. (2022) provides additional details on our weather-normalization methodology, as applied to a different dataset.

[27] https://www.caltrack.org/. CalTRACK is an open-source method that has received extensive stakeholder vetting.
[28] Few homes had their usage best explained by the intercept-only model. 14 electric and 11 gas projects had an intercept-only model as the best fit in the pre-project period. In the post-project period, 6 electric and 0 gas projects had a zero-intercept model as the best fit. It is possible that some of the homes with intercept-only electric models in the pre-project period did not have air conditionaing and added it; some of the homes with zero-intercept models for gas in the pre-period may have used a different home heating fuel.
[29] We use average degree days and not degree days derived from three-year average temperature, as degree days are generally understood to drive weather-dependent electricity and gas usage. Degree days based on average temperature could obscure variation over the three-year period.

4. Energy and cost outcomes

4.1 Results of energy usage data analysis

We received usage data for 546 Midwest Energy projects. We set aside some households because we could not determine pre- and post-project usage data windows with certainty from the Midwest program data. We also set aside 69 households that installed electric water heating through another Midwest Energy program at a similar time to installing their PAYS® projects (see section 4.1.1). Moreover, a small number of households were missing gas data. After dropping all the above-referenced households, our analysis generated estimates of changes in electricity usage estimates for 362 households and changes in gas usage for 357 households—about two thirds of Midwest dual-fuel customers who participated in the program.

Table 6 summarizes the average impact of the projects in our data (excluding water heating projects as discussed above). Overall, we find that households saved 15.2% of their annual electricity usage and 26.2% of their annual gas usage, which corresponds to annual usage reductions of 2,056 kWh and 219.8 therms.

Also in Table 6, we show the realization rate by fuel. This metric is the ratio of our average *ex post* estimate of changes in usage to the average *ex ante* savings estimate that Midwest Energy used to screen the projects. Both the electric and gas realization rates are about 83%, meaning that on average the projects' *ex post* calculated usage reductions were 83% of the *ex ante* estimated savings.

Other *ex post* studies of similar energy efficiency projects generally also find that *ex ante* savings predictions are overestimates of actual changes in usage. Relative to other realization rates for similar, non-PAYS® residential efficiency programs, 83% is within the range of results reported in the literature, and higher than many of them (see Appendix B for details). PAYS® program requirements for utilities to remedy installation errors may in part drive these relatively high realization rates, since installation errors are one reason that ex post savings fall short of ex ante estimates (Christensen et al. 2021).

Table 6. Average annual household savings impacts for Midwest Energy projects

Fuel	*Ex ante* estimated annual household savings	*Ex post* calculated annual household usage reductions	*Ex post* percent usage reduction	95% confidence interval	Realization rate
Electricity	2,473 kWh	2,056 kWh	15.2%	+/- 1.4%	83.1%
Gas	265.9 therms	219.8 therms	26.2%	+/- 3.5%	82.7%

At the individual project level, 77% and 89% of Midwest projects reduce electricity and gas consumption respectively. We are not surprised to find that some households increase electricity or gas usage. As Figure 2 shows, our calculated *ex post* usage impacts are quite variable, forming a distribution that spans large increases in load to near total reductions in load. We expect that these factors explain much of the observed variability and have observed similarly wide distributions in other work using the same *ex post* methodology (Deason, Murphy, and Goldman 2022, 2021). While our method normalizes for weather, we are not able to account for many other factors that influence energy usage, such as the economy, the installation of new appliances or equipment, changes in occupancy or other behavioral changes. These factors may influence usage both before and after a PAYS® project for reasons unrelated to the energy efficiency project installed. As a result, it is not uncommon for an *ex post* estimate of project impacts to differ substantially from the *ex ante* estimate at the household level. This difference does not necessarily indicate that the *ex ante* estimate was inaccurate.

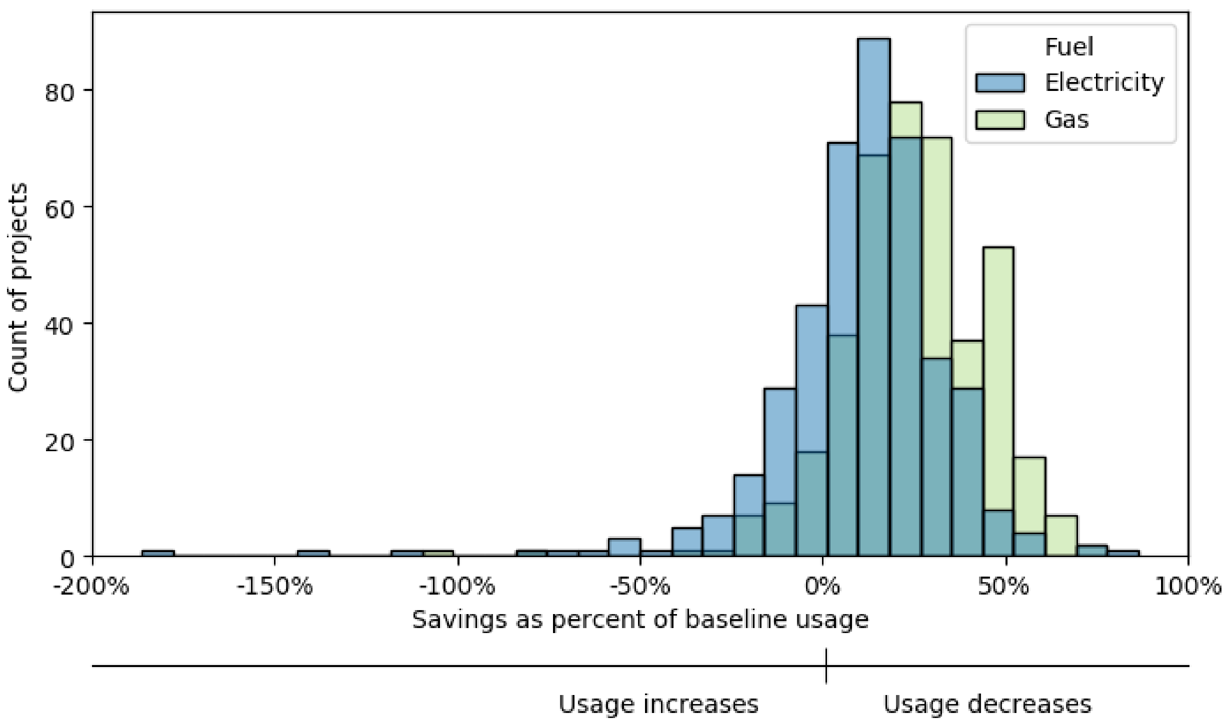

Figure 2. Distribution of *ex post* project percent usage changes by fuel

4.1.1 Treatment of non-PAYS® water heating electrification projects

Midwest Energy offers a rebate program for electric water heaters in parallel to their PAYS® efficiency offering. The Midwest Energy PAYS® program itself does not support water heating, (although some other PAYS® programs do), so the *ex ante* savings estimates that were the basis of Midwest's project eligibility assessments do not include their impacts. However, many PAYS® participants switched from gas to electric water heating in conjunction with participation in the PAYS® program.[30] According to Midwest Energy program staff, these water heating fuel switches were often driven by air quality concerns with internally vented gas water heaters brought on by PAYS® weatherization work.

[30] Midwest program staff believe that few participating households switched fuels for *space* heating, and we see no evidence on significant space heating fuel-switching in the usage data. Most Midwest Energy households heat with gas, both before and after program participation.

The replacement of gas water heating with an electric version alongside the PAYS® projects or during the pre- and post-metering period confounds our estimate of the impact of efficiency measures installed through the Midwest Energy PAYS® program. A decrease in gas usage and increase in electricity usage due to fuel-switching alongside the PAYS project or during the post-project metering period would inflate our estimates of gas usage reductions and deflate our estimates of electricity usage reductions from the efficiency measures. If the water heating were installed in the pre-project metering period, it would prevent us from establishing a valid baseline against which we could measure post-project performance.

Based on program participation records from Midwest Energy, we identified 69 households in our energy usage dataset that received rebates for electric water heaters at a time that could confound our analysis. The majority (n=60) of water heater replacements occurred at or around the same time as the installation of the PAYS® efficiency measures (after the pre-project metering period ended and before the post-project metering period began). The remaining nine water heater replacements occurred either during pre-project metering (n=8) or post-project metering (n=1).

Figure 3 demonstrates the potential bias of including these water heating projects. It shows the *ex ante* and *ex post* estimates of electricity and gas for projects with and without water heating installations. The solid line in each plot represents equal *ex post* and *ex ante* savings. As we expected, *ex post* electricity usage changes are generally lower than *ex ante* savings estimates (water heater projects are below the solid line) for projects with water heaters installed in conjunction with the PAYS® efficiency measures. For gas, we find the inverse: *ex post* usage reductions are higher than *ex ante* savings estimates (water heater projects are above the solid line). The results earlier in this section and elsewhere in this report do not include any PAYS® project households that participated in the water heater program inside that household's study period.

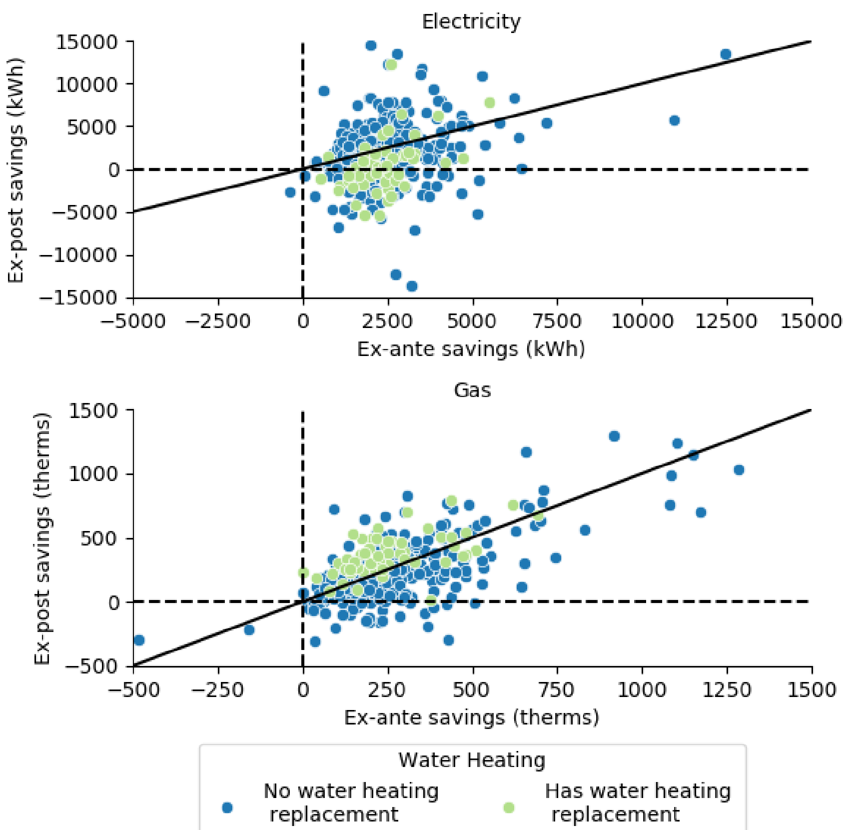

Figure 3. ***Ex ante*** **and** ***ex post*** **electricity and gas savings by water heating status**

4.2 Annual cash flow, net bill, and net present value impacts

PAYS® program design requires that *ex ante* estimated annual bill savings exceed the annual cost of the tariffed charge. Bill savings depend on electricity and gas retail prices, which change over time. Current PAYS® guidance—unlike many other energy programs—prohibits the use of escalation rates for electricity and gas prices when estimating pre-upgrade savings. Midwest Energy, however, does assume energy cost escalation,[31] and calculates *ex ante* estimated bill savings as the product of *ex ante* estimated electricity and gas savings and the escalated prices in each year of the installed measures' lifetime.

To evaluate Midwest Energy participant cash flow, we developed high and low electricity and gas prices based on historical rates and escalation factors used between 2015 and 2019 that Midwest shared with us. For each fuel, we use the minimum reported price during those years as the low price ($.0987/kWh and $.72/therm) and use the maximum average price over the study period produced by Midwest's

[31] Our understanding is that PAYS® guidance at the time the Midwest program launched in 2007 did not prohibit escalating energy costs.

escalation assumptions as the high price ($.162/kWh and $1.17/therm).[32] Next, we calculate average monthly net cash flow relative to pre-upgrade energy costs for each combination of low and high electricity and gas prices.

In the low electricity and gas price scenario, we estimate that the average household reduces electricity and gas costs by about $340 per year (see Figure 4). In the high electricity and gas price scenario, the average household reduces those costs by about $560 per year. A year of average monthly tariffed charges amounts to just over $500. Under all three price scenarios, bill savings exceed the tariffed charges for some households and not for others. For example, 56% of households see net annual bill savings in the high price scenario, while 30% see net annual bill savings in the low-price scenario. Overall, annual net bill changes are generally moderate, with weather-normalized energy bills changing by +/- 15% in 48% and 58% of the projects in the low- and high-price scenarios, respectively.

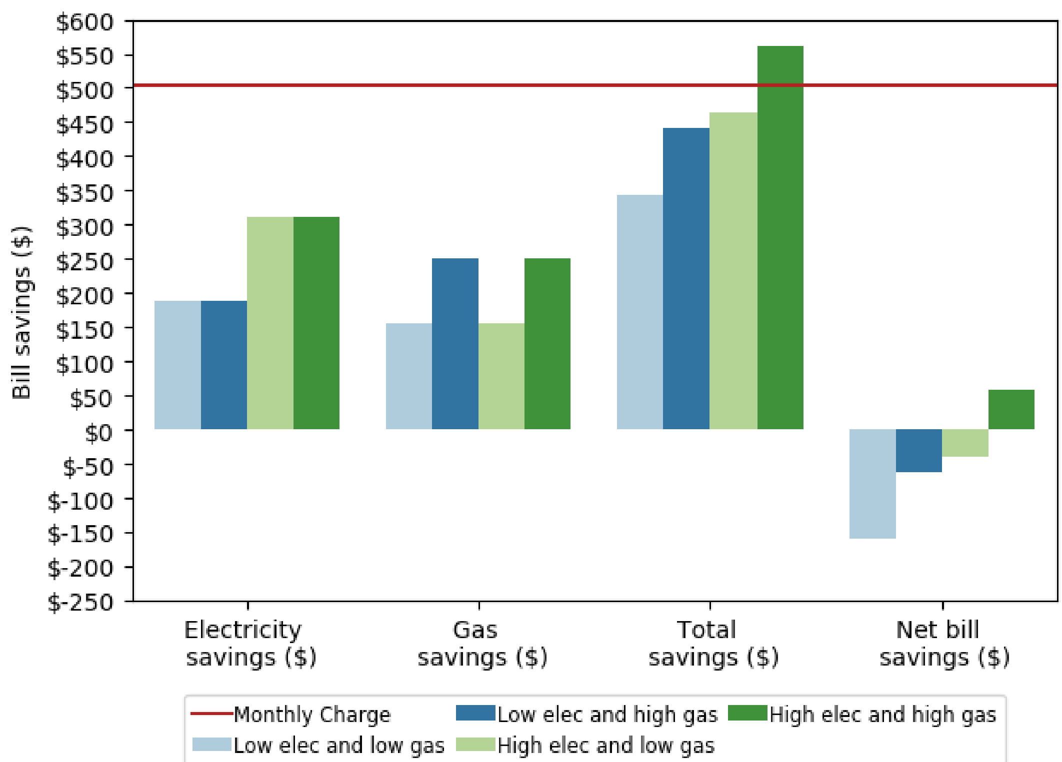

Figure 4. Average annual bill savings for each price scenario, compared to average annual tariffed charges

[32] In a given year, Midwest Energy applies electricity and gas escalation rates to that year's electricity and gas prices over a project's term in order to calculate expected bill impacts. The base fuel prices and escalation rates vary year-to-year. In each year that we have reported fuel prices and escalation factors, we calculate the average of the escalated electricity and gas prices over a 15-year period (reported loan term for Midwest projects). To find our high price for each fuel, we then take the maximum of those average escalated fuel prices. Note that we did not receive a full time series of electricity and gas prices charged by Midwest Energy during the project period, so could not use actual prices.

As noted above, Midwest Energy restricts the tariff term to 75% of the useful life of the projects. In the final years of a project's life, participants might expect to continue to receive bill savings[33] but do not pay tariffed charges. On the other hand, participant copays represent an additional up-front cost not captured by the cash flow analysis. We implemented a net present value calculation to account for both copays and out-year savings. Note that this calculation is not a full rendering of costs and benefits from the perspective of a PAYS® participant, as it does not account for the non-energy impacts that energy efficiency projects can generate (e.g. health and safety) (Hawkins et al. 2016); this calculation only accounts for total energy costs.

With all cash flows discounted at a 3% rate, we find that the share of households that enjoy positive net present value (NPV) over the project lifetime is very similar to the share with positive annual cash flow. This share remains 56% in the high price scenario and increases slightly to 32% in the low price scenario.[34] In both the high and low price scenarios, a smaller share of projects with copays have positive cost savings over the project lifetime relative to projects without copays. Table 7 summarizes these results.

These results demonstrate that fuel prices have a significant impact on our estimates of both annual cash flow and lifetime project cost savings. For both projects with and without copays, the share of projects with positive NPV in the high price is more than 20 percentage points higher than in the low scenario.

Table 7. NPV and cash flow by price scenario

Copay status	Electricity prices	Gas prices	Share of projects with positive annual cash flow	Share of projects with positive NPV
No copay	High	High	64%	71%
Has copay			52%	48%
Overall			56%	56%
No copay	Low	Low	30%	45%
Has copay			29%	25%
Overall			30%	32%

These results do not necessarily imply that energy shell and HVAC performance upgrades in some homes did not perform as expected. As noted above, participants may make choices unrelated to the projects that increase their energy use, such as taking in an elderly parent, or adding a pool or a second refrigerator. A study of the Appalachian Electric Cooperative PAYS® program (Kauffman 2021; Bickel 2022) found that ten households had positive net cash flow and the other ten did not (a share that is quite similar to our results). Based on telephone interviews and on-site investigations, the study

[33] Note that Midwest tariffed charges have 15-year terms, so the implicit assumption is that the measures have 20-year useful lives. This is an optimistic lifetime for HVAC equipment.

[34] The 56% of projects that have a positive NPV are not the same 56% of projects that have a positive cash flow—the result is coincidental. There are as many projects that have copays that offset positive annual cash flow as there are projects in which bill savings in out years offset negative annual cash flows and or copays to yield a positive NPV.

determined that seven of the ten cases of negative cash flow were attributable to changes in the number of occupants, occupancy patterns, or addition of new load (such as a swimming pool). The remaining three cases were due to bad heat pump settings which were subsequently corrected. Outcomes in the Midwest program are likely also due in part to changes in occupant behavior and other causes independent of the participant or program.

4.3 Monthly bill impacts

Annual estimates of cost savings describe the overall bill impacts that project participants face, but they obscure variation in cash flow over the year. In Figure 5, we show total dollar savings (electricity and gas bill savings combined), the average monthly charge, and net bill impacts by month for each of the four price scenarios. The total bill savings demonstrate the seasonality of the electricity and gas impacts: gas usage reductions drive bill savings in the winter and electricity usage reductions drive bill savings in the summer. Under the high price scenarios, these usage reductions provide seasonal net bill savings. In edge months such as April and September when usage - and usage reductions - are lower, average net bill savings are negative in all price scenarios.

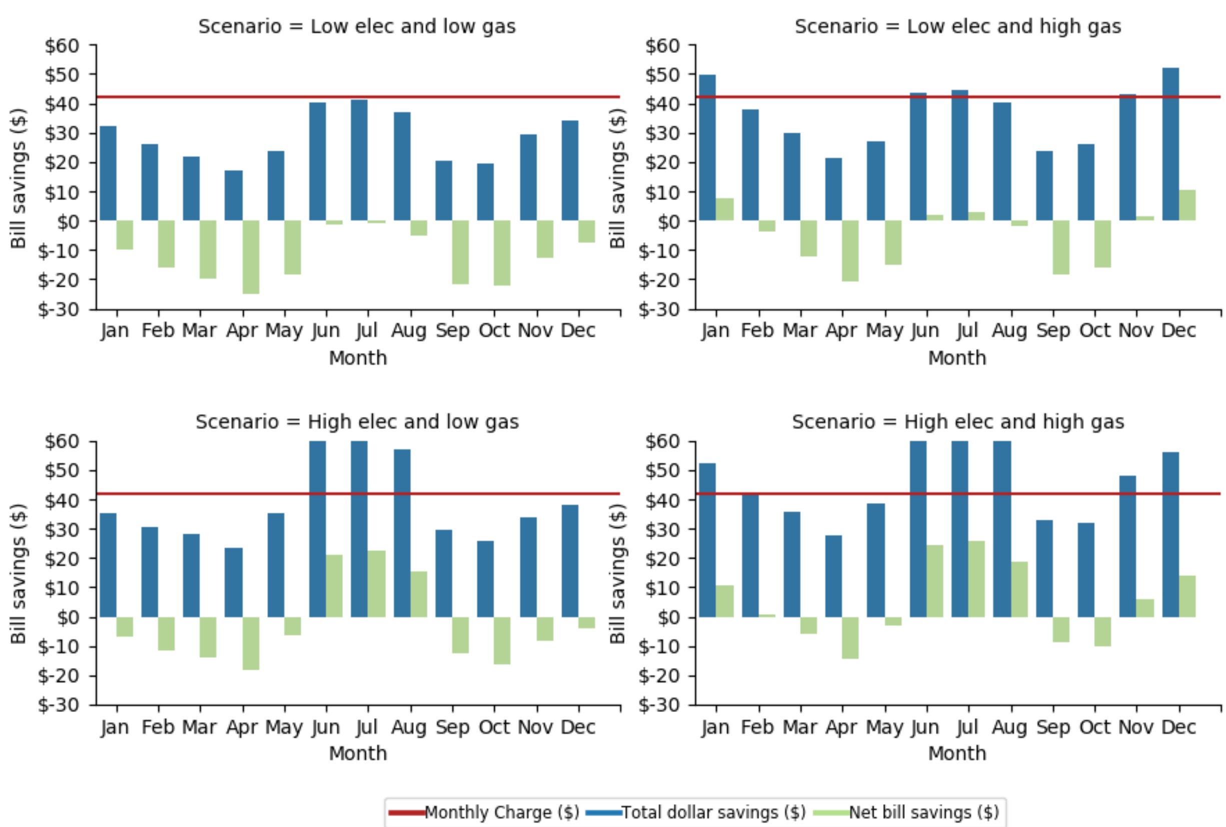

Figure 5. Monthly cash flows for Midwest projects by price scenario

Summer and winter are the seasons with highest energy bills among the participating households. Our results show that PAYS® participation smooths utility bill expenditures seasonally, providing the greatest reductions in use and cost during the highest-cost months. Relative to the pre-project period, the variance of participant monthly energy bills decreases in all fuel price scenarios. This reduction in bill volatility is likely valuable to households, especially those managing costs on a monthly basis, though we do not seek to quantify its value here.

4.4 Comparison to *ex post* energy usage results from other PAYS® programs

Next, we compare our estimate of electricity impacts in Midwest Energy's How$mart® program to three prior analyses of the performance of the Appalachian, Roanoke and Ouachita PAYS® programs using broadly similar normalized metered energy consumption methods (Kauffman 2021; Bickel, Ferguson, and Kauffman 2022; Bickel et al. 2022). None of these existing analyses develop an *ex post* estimate of gas usage changes (and many homes in these programs do not have gas service), so we restrict comparison to electricity impacts. Building stock and climate vary between these programs, so we expect some differences in usage reductions. For example, all Roanoke projects are retrofits of existing electric heating systems, so electricity usage changes from heat pump installations include both heating and cooling. In contrast, most Midwest households have gas heating, so electricity usage changes from heat pumps mostly result from cooling.

The usage reductions for the Appalachian, Roanoke, and Ouachita projects reflect these expected differences (Table 6). Electricity use reductions per household in the other programs are notably higher than our Midwest estimates in absolute terms and slightly higher in percentage terms. Given the prevalence of electric space heating in the other program service territories, this difference is logical, as many electrically heated homes in these programs replaced inefficient electric resistance heat with heat pumps.

Table 8. Average project usage reductions by program and fuel

Program	Average *ex post* household electricity usage reductions (kWh)	Average *ex post* electric percent usage reductions (%)	Project cost ($)	Project count
Appalachian	5,082	21%	$7,844	20
Ouachita	3,218	17%	$5,665	369
Roanoke	3,587	18%	N/A	388
Roanoke, excluding electrified homes	4,571	22%	N/A	299

5. Takeaways and potential program enhancements

5.1 Key conclusions

Four of the five PAYS® programs we reviewed serve populations whose incomes and levels of post-secondary education are well below the national average and whose unemployment rates are well above the national average. While we did not have household-level demographic data, we could associate each participating household with demographic information at the zip code level, and these data suggest that the programs reach areas that mirror their service territories. Therefore, based on best available evidence, it appears that these PAYS® programs are successfully reaching households in disadvantaged communities.

Most PAYS® participants significantly reduce their energy usage. A subset of homes increases their usage; this is also the case in other energy efficiency programs when analyzed with the same *ex post* methodology (see, e.g., Deason et al. 2022; Deason et al. 2021). We find that participating households receiving both electricity and gas service from Midwest Energy reduce electric usage by 15% and gas usage by 26% on average. Existing studies of the Roanoke and Ouachita PAYS® programs find electricity usage reductions of 22% (excluding households that switched from gas to electric space heating). and 17% on average. Savings potential from different PAYS® programs will vary depending on climate and existing housing stock. In some ways, the manner in which these projects are capitalized has little to do with their energy performance. However, as discussed above, PAYS® programs are designed such that *ex ante* estimated energy savings cover tariffed charges, and must take remedial action in cases where they do not if the shortfall is due to poor installation. Thus, PAYS® programs include a greater incentive to ensure that energy savings are realized than some other program designs. Realization rates for PAYS® programs are generally high compared to those measured in other programs, which may be at least in part due to these incentives.

Among Midwest Energy program participants, about half appear to reduce their energy costs enough to offset the tariffed charge, saving money in a normal weather year, while about half do not appear to generate enough energy cost savings to offset the tariffed charge. The precise percentages depend on assumed electricity and gas prices. Midwest Energy requires the monthly tariffed charge to be 90% or less of expected savings, and their tariffed charges average 85% of the expected savings. The projects realize 83% of their expected energy savings on average per our calculations, meaning that the average project comes very close to breaking even. Household-level results from a small sample of Appalachian projects (Kauffman 2021) show similar results.

Midwest Energy How$mart® program participants report higher levels of satisfaction than Midwest member-owners overall. In 2015 97% and 96%, respectively, of How$mart® households reported satisfaction and value perception scores of 8-10 on a 10 point scale, compared to 85% and 68% respectively for general Midwest households (Dreiling 2015).

Even for households whose energy costs go up, program participation may still be the least-cost method of upgrading their home's energy systems, may ease interactions with contractors, and may provide valuable oversight of the installation. Beyond bill impacts, the upgrades themselves generally provide improved comfort, health, and safety. Rental households or those with no or low credit scores might not otherwise be able access the upgrades at all.

The cost test for PAYS® programs compares the household's total energy costs after the project (including the costs of the measures) to the household's cost prior to the project. PAYS® participants cover the full cost of the measures installed (plus the utility cost of capital) via the tariffed charge, not merely the incremental cost of more efficient measures. Most participating households would have needed to replace their HVAC systems during the cost recovery period, and their total energy costs of doing so outside the programs (e.g., by paying cash or taking up higher-interest rate financing) might well have been higher.

In our view, the energy and cost impacts of the Midwest Energy projects, and of the other PAYS® programs available in the literature, are within reasonable expectations. Given the inherent variability in household energy consumption and cost, volatility in energy prices, and the influence of non-project factors, we would not expect that every participating household's net energy costs would go down. PAYS® programs include a number of features that promote participant cost savings, including: requiring *ex ante* estimated savings to exceed the tariffed charges; requiring the tariff term to be less than the effective useful life of the project; and requiring program administrators to take remedial action if projects do not perform as expected. While we cannot directly test this, we expect that these program features reduce the share of participants who see their costs rise.

5.2 Potential program enhancements

Programs that wish to increase the likelihood that participants' net monthly costs go down can set more restrictive ratios of allowed tariffed charges to *ex ante* savings - as three of the reviewed PAYS® programs do. A lower ratio, such as 80% or 75%, would likely result in a slightly larger share of program homes experiencing net bill savings each month. However, there are tradeoffs to confront when considering where to set this threshold. Lower thresholds would also mean that more projects would require copays to qualify and that average copays would be slightly higher. Some households likely lack the means to make copays. Ultimately, these thresholds represent a value judgment on tradeoffs between (a) the level of certainty in household-level bill savings, (b) the need for copays, and (c) the number of projects that would qualify absent copays.

Further financial support for potential PAYS® program participants—particularly low-income households and households in disadvantaged communities—could help drive projects. Such assistance could take different forms. For example, an up-front rebate would lower principal amounts in similar fashion to a copay. Such support, if available to all participants, might also enable households who would already participate to include additional measures, saving more energy and producing more co-benefits.

Notably, the Inflation Reduction Act of 2022 introduced the HOMES rebate program.[35] HOMES rebates cover a portion of the up-front cost of energy efficiency upgrades that achieve certain *ex ante* or *ex post* energy usage reduction outcomes. In particular, projects that achieve *ex ante* estimated savings of 20-35% of pre-project energy consumption can receive a $2000 HOMES rebate, and those achieving *ex ante* estimated savings of 35% or greater can receive a $4000 rebate. As noted in Table 5, the majority of PAYS® project copays across the five PAYS® programs we review are below $2000. 56% of Midwest Energy PAYS® households achieved *ex ante* estimated energy savings of 20-35%, and 21% achieved 35% or more. When calculated on a household level, the IRA rebates (if available at the time)[36] would have eliminated copays for almost half (49%) of those households that made them, and substantially reduced those copays for other households that qualified. Moreover, these rebates are doubled for low- and moderate-income households. We do not have household-level income data to determine which or how many of the participating Midwest Energy households would have qualified for these larger rebates, but some likely would have. These calculations illustrate the large potential impacts of IRA or similar rebates for the participant economics of PAYS® projects. State energy offices may wish to consider supporting utility adoption of PAYS® or other tariffed on-bill programs as a complementary approach to the IRA rebates. State energy offices could consider issuing guidance on program design; facilitating sourcing of capital; and engaging in relevant regulatory proceedings.

Finally, our analysis of project copays suggests that measure types have a significant influence on the need for copays. In particular, PAYS® projects would do well to incorporate air and duct sealing wherever possible, as fewer projects that include these measures require copays to qualify, all else equal.

6. Future work

As discussed in this report, energy and cost impacts of PAYS® projects differ by household, and some participating households' total energy costs (including post-project energy costs plus costs to repay upfront capital investments) go up relative to their pre-project costs. This is also the case in other energy efficiency programs (see, e.g., Deason et al. 2022; Deason et al. 2021). Follow-up with program participants could determine whether participants' energy bills that go up do so because of added loads that are not part of the projects, other behavior change, overestimation of savings *ex ante* by savings estimation tools, or upgrade installation error. Sponsoring utilities and program operators recognize that the PAYS® system and similar program designs would benefit from analytic tools currently in development that enable them to distinguish the impact of behavioral choices on energy usage from that of program error or equipment failure, as well as investigation protocols for ambiguous cases (see

[35] IRA also introduced the High-Efficiency Electric Homes Rebates. These rebates would have limited applicability to the Midwest program we study here, as these rebates support electrification of space heating and most Midwest homes in the program heated with gas both before and after their projects. For other PAYS programs, especially those promoting electrification, the HEEHRA rebates could also have a very significant impact on the need for copays.

[36] Note that equipment and installation costs have risen since these projects were implemented, so our simple calculation somewhat overstates the impact of these rebates on future projects.

Goldman, Theurer, and Bickel 2022). A better understanding of the drivers of lower-than-expected savings can help PAYS® program administrators target households to reduce the share of projects in which net energy costs go up (see also Christensen et al. 2021).

This report reviews the energy and cost outcomes for PAYS® participants. PAYS® projects, and other energy efficiency projects, may also improve comfort and health outcomes and increase property values (Sutter et al. 2020). Analysis of these dimensions would help determine the overall impact of these programs on participating households.

A number of PAYS® programs—and similar tariffed on-bill programs that differ from the PAYS® model in one or more dimensions—have recently launched or will launch soon.[37] A review of program design and delivery experiences on topics other than energy and cost outcomes, such as successful engagement of capital sources, recruitment of participating households, and interaction with participating contractors, will likely improve program practice. The U.S. Environmental Protection Agency maintains a resource on inclusive utility investment programs[38] that centralizes and disseminates such lessons learned.

[37] See https://www.energystar.gov/products/current_program_information for a list of programs..
[38] See https://www.energystar.gov/products/inclusive_utility_investment.

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Appendix A. Copay regression analysis

We perform two regression analyses to understand trends in copays in PAYS® projects. First, we use a logistic regression to predict how the likelihood of a copay changes depending on the PAYS® program in question and which of four measure categories (HVAC, insulation, air and/or duct sealing, and LED lighting) that the project included. Next, we use ordinary least squares (OLS) regression on projects *with copays* to estimate how copay amount relates to each program and measure category. In both regressions, we estimate the impact of the Appalachian, Kentucky, Ouachita, and Roanoke programs relative to Midwest Energy's program.

We summarize the logistic and OLS regressions in tables A-1. To the right of each explanatory variable, the table presents the variable's coefficient and, in parentheses, standard error. For the logistic regressions, we report average marginal effects, which represent the change in the probability of a copay associated a project taking place in particular program or including a given measure. We find statistically significant differences in the probability of a copay relative to Midwest Energy at a 99% confidence interval in all programs except Appalachian. This difference is greatest for projects in Roanoke, which are 46% less likely than projects in Midwest to have a copay, controlling for installed measure categories. We also find that the type of measures included in projects affects the likelihood of copays, regardless of the program in which the project takes place. The inclusion of HVAC measures has the largest effect, increasing the chance of a copay by 22%. Air and/or duct sealing, in contrast, is associated with a 12% decrease in the chance of a copay. These results are consistent with the higher cost of HVAC measures and lower cost of air and/or duct sealing measures.

For projects that have copays, we do not find statistically significant program effects at a 95% percentile. However, we find statistically significant effects associated with the measures installed in a project. On average, in projects with copays HVAC and insulation measures increase copays by about $1400 and $400 respectively.

Table A-1. Regression results

	Project has copay (Logistic)	Copay amount ($) (OLS)
Intercept		637.610**
		(302.457)
Appalachian	-0.0777	-2686.746
	(0.089)	(1708.526)
Kentucky	-0.1001***	-511.029
	(0.038)	(313.680)
Roanoke	-0.4755***	-2792.888
	(0.086)	(1847.658)
HVAC	0.2167***	1451.903***
	(0.055)	(270.469)
Insulation	0.0776***	389.652**
	(0.029)	(194.772)
Air/duct sealing	-0.1202***	324.023
	(0.036)	(302.384)
LED lighting	0.0615	2506.566
	(0.082)	(1855.990)
Observations	1,151	590
Pseudo R^2	.1343	
R^2		0.048
Adjusted R^2		0.037
Residual Std. Error		2298.358 (df=582)
F Statistic		4.718*** (df=7; 582)
Note:		*p<0.1; **p<0.05; ***p<0.01

Appendix B. PAYS® comparator realization rates

The following table reports realization rates for several whole home retrofit and weatherization programs. The programs are not a representative sample but they do illustrate the range of realization rates in the literature. *Ex post* usage changes can differ from *ex ante* savings estimates for various reasons: assumptions in engineering calculations; failure to consider historical usage in *ex ante* estimation; post-project changes in equipment performance; and changes in occupant behavior (Christensen et al. 2021; Navigant 2020).

Table B-1. Realization rates from other studies

State	Program	Savings metric	Realization rate	Source
California	Home Upgrade Program	Electricity	40%	DNVGL 2019
	Home Upgrade Program	Gas	66%	
	Advanced Home Upgrade Program	Electricity	16%	
	Advanced Home Upgrade Program	Gas	35%	
Illinois	Weatherization Assistance Program	Total MMBtu (electricity and gas)	51%	Christensen et al. 2021
Massachusetts	Low-Income Multifamily	Gas	80%	Reeves et al. 2015
Massachusetts	Home Energy Services	Gas	73%	Navigant 2020
Wisconsin	Better Building Neighborhood Program	Total energy bill expenditures	68%	Allcott & Greenstone 2017