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ABSTRACT

We review the energy and financial outcomes of 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 through a tariff attached to the home's utility meter, designed to be offset by project savings. We find that the five programs we study generally serve customers living in zip codes with levels of income and education below the national average and unemployment rates above the national average, demonstrating their potential to improve equity in energy efficiency adoption. Using weather-normalized analysis of energy consumption data, we show that most customers of 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. These results are similar to existing analyses of PAYS® programs in North Carolina, Arkansas, and Tennessee. About half of participating Midwest households generate sufficient energy cost savings to cover their monthly tariff. Various factors, including changes in occupant behavior, program error, causes independent of the customer or program, or some combination thereof may explain lower-than-expected cost reductions in some projects. Given the inherent variability in annual household electricity consumption, we feel these programs are enabling energy efficiency improvements and their attendant co-benefits, including occupant health and comfort and reduced carbon emissions, while reasonably balancing energy savings and tariff costs. Pairing PAYS® with additional financial assistance, as well as promoting cost-effective measures such as air and duct sealing, could further broaden program participation by enabling additional projects to meet PAYS® program eligibility rules.

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 savings to pay the up-front cost of energy efficiency upgrades. Unless homeowners can draw equity from their homes, 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.[1] Pay-As-You-Save (PAYS®) programs[2] represent

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

[2] 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://eeivt.com/wordpress/PAYS®-essential-elements-minimum-program-requirements-2/

one of these program types. PAYS® programs are part of a broader category of programs known as Inclusive Utility Investment programs.[3]

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 finance energy efficiency upgrades – with no up-front expense unless they make a copay – without taking on debt and without needing to meet credit score or debt-to-income thresholds to qualify. By requiring expected energy bill savings to exceed the cost of the tariff 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.[4] 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.

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 customer copays
- Assess the energy savings, utility bill savings, 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. 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 financial 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.

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[3] https://www.energystar.gov/products/inclusive_utility_investment

[4] Per LibertyHomes and the Energy Efficiency Institute, Inc. PAYS®-style programs had supported 5867 total projects as of December 30, 2021. See http://www.eeivt.com/wp-content/uploads/2021/12/2021-PAYS®-Status-Update_12.30.21rev.pdf.

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 pays for all or a portion of the capital cost of an energy project[5] 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 investment over time through a fixed tariff[6] for a specified term (often 10-15 years), with the obligation for repayment staying attached to the location and its electric meter. During the term of the tariff, the utility owns the newly-installed measures. This tariff is placed on the customer's electricity bill and treated in similar fashion to any other customer bill charge, with the same consequences of nonpayment,[7] until the utility has recouped its cost at the end of the term.[8] Because the tariff is attached to the meter, not the resident, it transfers to the new occupant if a participating property is sold before the end of the tariff's term. 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 (generally 75%-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 tariff cost.

Unlike a loan recipient, a PAYS® participant does not take on debt when enrolling. Approval for PAYS® projects is generally based only on the savings-to-investment ratio (SIR) of the project, rather than customer credit score and debt-to-income ratio.[9] 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 ownership status,[10] credit, and financial characteristics of the participating household. 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 tariff must not exceed some percentage of expected average monthly savings on all fuels (or water with associated hot water energy savings combined) 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 the cash flow

[5] 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).
[6] A tariff defines the way a utility or other energy provider charges a customer for services provided.
[7] These consequences can include service shutoff if a customer becomes seriously delinquent.
[8] According to data on PAYS® programs gathered by Liberty Homes, shares of uncollectibles are below 1% for all active programs where data are available. See http://www.eeivt.com/wp-content/uploads/2021/12/2021-PAYS®-Status-Update_12.30.21rev.pdf.
[9] Some PAYS® programs consider the customer'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.
[10] Unlike most programs that extend capital for household energy efficiency projects, renters can participate in PAYS® programs. Tenants who pay their own electricity bills are responsible for paying the tariff, which is designed to be offset by *ex ante* project savings estimates and therefore not increase total energy costs.

test, it can make a copayment to buy down the principal amount to (or below) the amount allowed given the expected project savings.

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.

PAYS® participants and projects

In this section, we characterize PAYS® program participants and projects using detailed project information generously furnished by five PAYS® programs. 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[11]	Share of *ex ante* estimated savings available for cost recovery
U-Save Advantage	Appalachian Electric Cooperative	EEtility	2019 - present	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%[12]

Each dataset included project locations, costs, and the types of measures installed. 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

[11] Total project counts for U-SAVE Advantage, Ouachita HELP, and Upgrade to $ave are from Liberty Homes and the Energy Efficiency Institute 2021. Project counts from How$mart KY and Midwest Energy How$mart are from data reported to us by the programs themselves.

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

Roanoke, the data only covered projects performed by their current program administrator, EEtility, which began administering the program in 2017.

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 where participants live 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 at the program level. Table 2 summarizes these participant-weighted trends 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	Household income	Detached single family homes	Mobile homes[13]
Appalachian	94.8%	3.7%	15.9%	6.2%	$62,145	68.7%	19.8%
Kentucky	96.9%	3.1%	14.9%	7.8%	$51,633	65.6%	22.8%
Midwest	95.1%	2.7%	35.0%	2.9%	$73,285	69.6%	4.0%
Ouachita	60.1%	39.8%	14.9%	8.1%	$51,283	74.0%	12.2%
Roanoke	46.1%	52.0%	15.3%	7.9%	$54,047	63.8%	24.6%
National	75.3%	14.0%	32.1%	5.3%	$88,607	61.6%	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. We also find that in participant zip codes, shares of single-family housing are slightly higher than the national average and that, except for Midwest, shares of mobile homes 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.[14] We did not find large differences between the participant and service territory demographics, which

[13] We include mobile homes and doublewides in this category

[14] 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.

suggests that the programs are not disproportionately operating in particular areas of their service territories.

Project characteristics

Measures

In Table 3, 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.

Table 3: Share of projects in our dataset 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[15]	92.0%	62.9%	84.7%	3.4%
Midwest	96.8%	43.1%	15.1%	0%
Ouachita	92.7%	0%	93.9%	95.0%
Roanoke	90.1%	32.1%	85.8%	90.1%

Note: The data we received on Ouachita projects indicate than none of the projects we received included insulation; however, we are not sure this is the case.

Project Costs and Financing

In Table 4, we summarize average project financial characteristics. The total customer cost excludes any utility incentives.[16] Overall, customer costs across the programs are quite similar, which is not surprising given that the programs, for the most part, installed similar measures.

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 allowed length of the cost-recovery period; and the installation contractor's labor, materials, and equipment prices. Where one or more of these factors is unfavorable, savings may not be sufficient to cover the entire cost of the upgrades. PAYS® programs address this shortfall by allowing customers to make an up-front copayment (copay) that covers the difference between the total job cost and the amount covered by the utility investment plus any incentives. Some programs, such as those operated by EEtility, often make two offers to their customers: a weatherization-only upgrade offer that does not require a copay (always offered)

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

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

and an offer that also includes a new HVAC system, which may require a copay (often but not always offered). Other programs, like Midwest, do not always offer a no-copay option.

Table 4. Project financial characteristics

		Appalachian	Kentucky	Midwest	Ouachita	Roanoke
All projects	Total customer cost (tariffed amount plus copay)	$7704	$7323	$9659	$8247	$6975
	Share of projects with a copay	52.60%	47.50%	73.60%	31.30%	14.60%
	Payment as share of *ex ante* expected savings	77.50%	76.20%	84.70%	76.80%	77.60%
	Ex ante expected monthly savings ($)	$62.44	$47.23	$50.24	$74.11	$78.19
	Monthly payment ($)	$48.39	$42.78	$41.49	$56.44	$56.20
	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
Projects without copay	Total tariffed amount (including cost of capital)	$6269	$6418	$6391	$7525	$6469
	Total customer cost (tariffed amount plus copay)	$6269	$6418	$6391	$7525	$6469
Projects with copay	Total tariffed amount (including cost of capital)	$6932	$6205	$8145	$8067	$8036
	Average/ median copay ($)	$2027/ $2008	$2116/ $1250	$2687/ $1882	$1765/ $1432	$1890/ $1725
	Total customer cost (tariffed amount plus copay)	$8960	$8322	$10,832	$9832	$9925

Among projects with copays, average copays for all programs fall between $1700 and $2700 while median copays fall between $1200 and $2100. In all programs, the average copay exceeds the median copay, which reflects the presence of some projects with large copays. The frequency of copays varies substantially by program. 15% of Roanoke's and 30% of Ouachita's projects have copays while about half of Appalachian and How$mart KY and nearly three quarters of Midwest projects include copays. Via regression analysis, we find statistically significant relationships at a 95% confidence interval between measure types and the frequency and size of copays. When controlling for program effects, projects with HVAC are 22% more likely to have a copay and projects with insulation are 8% more likely to have a copay, while 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 $1,400 and the installation of insulation increases average copay amounts by $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 1, Midwest's customers have the highest zip code-based income and may be more able to make copays.

The utilities that sponsor these five programs all access various forms of low-cost capital to invest in these projects, such as loans from the U.S. Department of Agriculture, 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%.

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 savings are all about two to five percentage points below these thresholds. A notable exception is the Kentucky program, which permits a tariff amount up to 90% of expected savings while in practice the tariff averages only 76% of expected savings. Expected savings vary somewhat between programs, which may reflect differences in climate, energy prices, and baseline conditions of project households, program targeting practices,[17] or the types of projects that qualify under each program's eligibility rules.

Energy and cost outcomes

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 (Bickel, Ferguson, and Kauffman 2020; Optimiser 2018). 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 project for reasons unrelated to the energy efficiency measures installed. If a 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 electricity 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.

[17] For example, Roanoke began targeting high-usage customers partway through its program.

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.[18] 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, though 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.

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, 2014, and 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.

Treatment of 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 calculations that were the basis of Midwest's project eligibility assessments do not include their impacts. However, many PAYS® customers switched from gas to electric water heating in conjunction with participation in the PAYS® program.[19] 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.

The replacement of gas water heating with an electric version would decrease gas usage and increase electricity usage due to fuel-switching, which would confound our estimate of the impact of efficiency measures installed through their PAYS® program. We identified households in our energy usage dataset that received rebates for electric water heaters using program participation records from Midwest Energy. We then excluded any PAYS® project household that participated in the water heater program inside that household's study period (from the start of its pre-project meter data to the end of its post-project meter data). The results that follow do not include these projects.

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

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

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.[20] The weather normalization involves the following steps:

- Estimate how reported electricity and gas usage change with *observed* cooling and heating degree days (CDD and HDD) 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 coefficient of determination (R^2)) from a range of balance points for heating and cooling degree days, respectively. We also consider models that do not include HDD and CDD terms. When these models fit best, this indicates that a household's electricity or gas usage is not weather sensitive. To account for the three-year average usage in the pre-project data, we calculated the average heating and cooling degree days in each month over that three-year period.[21]

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, and also set aside 69 households who participated in the water heating program as described above. Moreover, a small number of households were missing gas data. After dropping all the above-referenced households, our analysis generated electricity savings estimates for 362 households and gas savings estimates for 357 households.

Table 5 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 savings of 2,056 kWh and 219.8 therms.

Also in Table 5, we show the realization rate by fuel. This metric is the ratio of our average *ex post* savings estimate 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 savings were 83% of the *ex ante* estimated savings. 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

[20] https://www.caltrack.org/. CalTRACK is an open-source method that has received extensive stakeholder vetting.
[21] 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.

them (see, e.g., Reeves et al. 2015; DNVGL 2019; Christensen et al. 2021). In other words, similar *ex post* studies generally find that *ex ante* savings predictions are overestimates. While savings estimation methods vary among PAYS® programs, program design features that hold the programs and sponsoring utilities responsible for ensuring that savings materialize may provide a useful incentive for ensuring relatively accurate savings estimates.

Table 5: Average annual household savings impacts for Midwest project

Fuel	*Ex ante* estimated annual household savings	*Ex post* calculated annual household savings	Percent savings	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 project households reduce electricity and gas consumption respectively. We are not surprised to find that some households increase electricity or gas usage. As Figure 1 shows, our calculated *ex post* savings are quite variable, forming a distribution that spans large increases in load to near total reductions in load. Since we do not have a control group nor details on non-project changes in the participating households, we are not able to account for factors other than weather that influence energy usage, such as the economy, the installation of new appliances or equipment, changes in occupancy or other behavioral changes. We expect that these factors explain much of the observed variability and have observed similarly wide savings distributions in other work using the same *ex post* methodology (Deason, Murphy, and Goldman 2022, 2021).

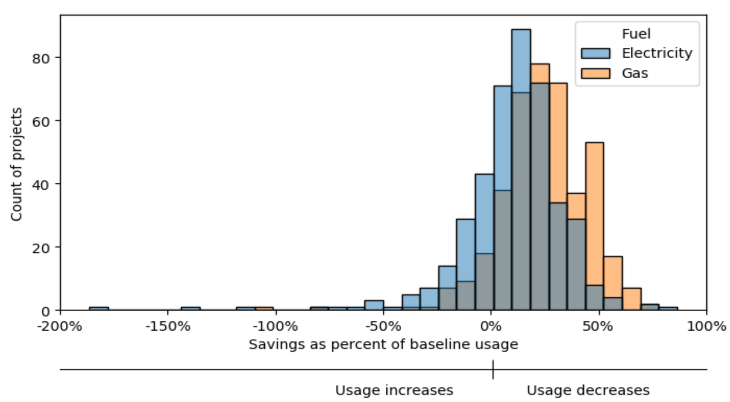

Figure 1: Distribution of project percent savings by fuel

Cash flow and net bill impacts

PAYS® program design requires that *ex ante* estimated annual bill savings exceed the annual cost of the tariff 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,[22] 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 customer 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 $.72/therm) and use the maximum average price produced by Midwest's escalation assumptions during the study period as the high price ($.162/kWh and $1.17/therm). 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 (Figure 2). In the high electricity and gas price scenario, the average household reduces those costs by about $560 per year. A year of average monthly tariff 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.

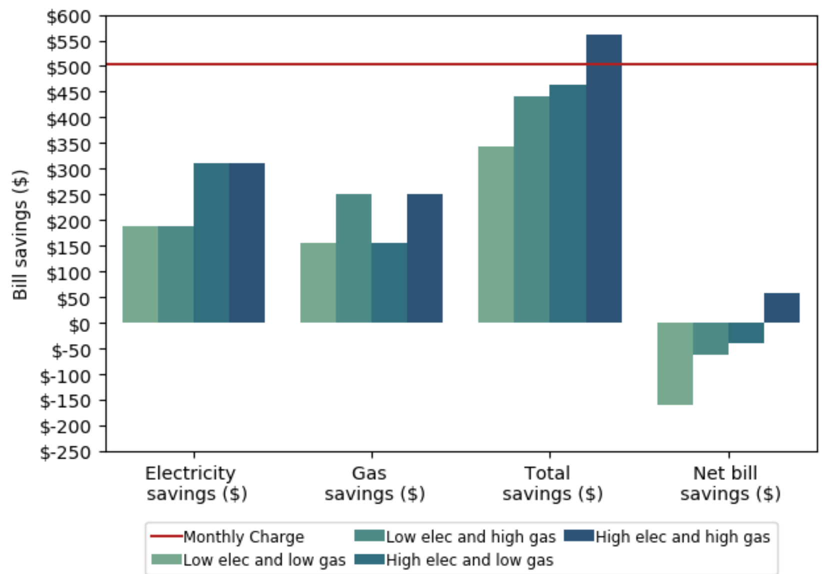

Figure 2: Annual cash flows by price scenario

As noted above, Midwest Energy restricts the tariff term to 75% of the useful life of the projects. In the final years of project life, customers might expect to continue to receive bill savings but do not pay tariff charges. Higher bill savings in these years would improve the total economic value of the projects to households.

These results do not necessarily imply that energy shell and HVAC performance upgrades in some homes did not perform as expected. Participants may make choices that increase their energy use, such as taking in an elderly parent, or adding a pool or a second

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

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 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 customer or program.
Annual estimates of savings describe the overall bill impacts that project participants face, but they obscure variation in cash flow over the year. In Figure 3, 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 savings: gas usage reductions drive bill savings in the winter and electricity usage drive bill savings in the summer. Under the high price scenarios, these savings provide seasonal net bill savings. In edge seasons such as April and September when usage - and savings - are lower, average net bill savings are negative in all price scenarios.

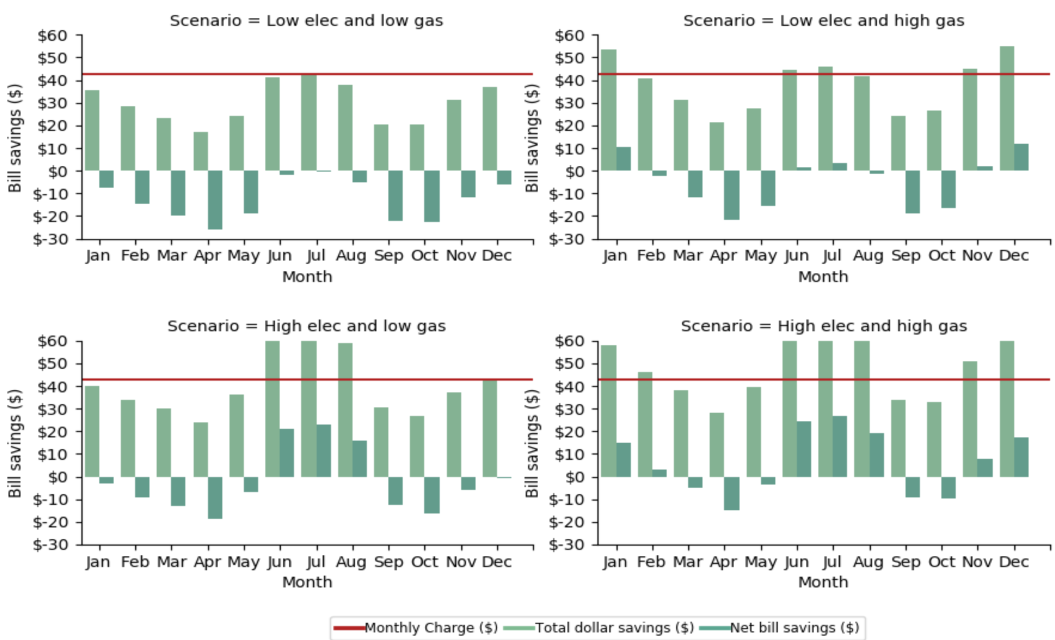

Figure 3: Monthly cash flows for Midwest projects by price scenario

Summer and winter are the seasons with highest energy bills among the participating households. Under the current tariff design, our results show that PAYS® participation likely smooths utility bill expenditures seasonally, providing the greatest reductions in use and cost during the highest-cost months.

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 2020; Optimiser 2018). None of these existing analysis develops an *ex post* estimate of gas savings (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 savings levels. For example, all Roanoke projects are retrofits of existing electric heating systems so electricity savings from heat pump installations include both heating and cooling. In contrast, most Midwest households have gas heating, so electricity savings mostly result from cooling.

The savings for the Appalachian, Roanoke, and Ouachita projects reflect these expected differences (Table 7). 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 Ouachita and Roanoke service territories, this difference is logical. A realization rate of 76% in Roanoke is comparable to our estimate of 83% in Midwest, while the realization rate in the Appalachian program is lower at 60% (though the sample size is only 20 homes so this difference may reflect random variation).

Table 7: Average project savings by program and fuel.

Program	Average *ex ante* household electricity savings (kWh)	Average *ex post* household electricity savings (kWh)	Average *ex post* electric percent savings (%)	Realization rate	Project cost ($)	Project count
Appalachian	8,470	5,082	21%	60%	$7,844	20
Ouachita	N/A	3,593	22.1%	N/A	$5,773	65
Roanoke	6,991	5,348	23.0%	76%	$6,868	120

The savings estimates reported in this table do not include the effect of comparison groups. The Roanoke evaluation did include an estimate of program savings net of a comparison group. So that we can better compare the programs in like terms, we only present the Roanoke savings exclusive of the comparison group.

Takeaways and potential program enhancements

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, in the process broadening access to energy efficiency improvements and associated co-benefits.

Most PAYS® participants significantly reduce their energy usage. 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 (excluding households that switched from gas to electric water heating). Existing studies of the Roanoke and Ouachita PAYS® programs find electricity savings of 23% and 22% on average (excluding households that switched from gas to electric space heating). 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-charge costs, 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.

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 tariff. The precise percentages depend on assumed electricity and gas prices. Midwest Energy requires the monthly tariff to be 90% or less of expected savings, and their tariffs average 85% of the expected savings. The projects realize 83% of the expected energy savings on average per our calculations, meaning that the average project comes very close to break-even. Given the inherent variability in annual household electricity consumption, we feel these programs are successfully enabling energy efficiency improvements and their attendant co-benefits, including occupant health and comfort and reduced carbon emissions, while reasonably balancing energy savings and tariff costs.

Midwest Energy How$mart customers do not seem dissatisfied with bill outcomes, as they report high levels of satisfaction. In 2015 97% and 96%, respectively, of How$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 customers (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. Rental households or those with no or low credit scores might not otherwise be able access the upgrades at all. Moreover, PAYS® programs may facilitate interactions with contractors, and may provide valuable oversight of installations. Beyond bill impacts, the upgrades themselves generally provide improved comfort, health, and safety as well as carbon emissions reductions from reduced energy consumption.

Our analysis shows that projects with air and duct sealing measures need copays less often, all other factors held equal; encouraging uptake of these cost-effective measures may help additional projects meet program eligibility thresholds, thereby scaling up participation.

Further financial support for potential PAYS® program participants - particularly low-income households and households in disadvantaged communities - could also help qualify projects and scale programs. Such assistance could take different forms - for example, an up-front rebate would lower principal amounts in similar fashion to a copay, while funds that reduce the cost of capital (an "interest rate buydown") would lower monthly tariff amounts instead. 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.

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