OUACHITA HELP PAYS® RESIDENTIAL ENERGY EFFICIENCY PROGRAM EVALUATION

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CONTENTS

EXECUTIVE SUMMARY

Ouachita Electric Cooperative contracted with OptiMiser LLC in October, 2017, to conduct an evaluation of the energy savings realized by the program. This report reports the results of that evaluation. This evaluation is restricted to the electric savings for participants who received program improvements during the study period. The data provided by Ouachita Electric Cooperative included program data for 198 households, including the improvements implemented and date of implementation, as well as utility bill histories for a subset of participants.

Utility data were compared to contemporaneous weather data to generate weather-normalized usage before and after improvements for each home. Reductions in usage were analyzed to identify the relationship between improvements and savings. Measures of cost effectiveness were generated using several standard measures.

SUMMARY OF FINDINGS

Our principal findings include:

1. Of the 198 program participants, 71 participants had sufficient data to yield savings estimates.
2. Participants who did not switch from fuel to electric heat saved an average of 3,593 net kWh per year, which represents a savings 22% of their prior electric usage.
3. Participants with higher prior usage saved more, averaging over 30% savings.
4. Apartments had higher savings, 24%, than single family homes at 22%.
5. Fuel switching homes saved 25%, compared to 22% for non-fuel switching homes.
6. Multivariate regression analysis produced these estimates of average savings by measure:
    a. HVAC measures contributed the most to savings, an average of 2,826 kWh per year for non-fuel switching homes, and up to 3,464 when fuel savings for fuel switching homes are included in the average.
    b. Air sealing was the next largest contributor, saving an average of 2,264 to 1,741 kWh, excluding and including fuel switching, respectively.
    c. Insulation saved an average of 771 to 980 kWh per year.
    d. Ducts and LED had negative estimates of savings, presumably because of interactions with other measures in the regression models.
7. The sample of participant homes with savings estimates was too small to identify meaningful differences between contractors on the average savings they achieved on their jobs.

8. Cost effectiveness was assessed using two measures: savings-to-investment ratio (SIR), and the cost of conserved energy (CCE).
9. The SIR is the ratio of the present value of costs of the program, to the present value of future savings. The total utility rate varies for participants, ranging by county from $0.12 to $0.16 per kWh. Using these costs, the SIR for this program ranges from 1.54 to 2.57.
10. The CCE computes the net present value of the costs versus savings from the program, resulting in what is called the levelized cost per kWh saved.
    a. The CCE cost for total savings is $0.103 without fuel switching participants, and $0.090 when fuel switching participants are included and their fuel savings included.
    b. The CCE cost for HVAC savings is $0.089 without fuel switching participants, and $0.078 when fuel switching participants are included and their fuel savings included.
    c. The CCE cost for air sealing savings is $0.019 without fuel switching participants, and $0.024 when fuel switching participants are included and their fuel savings included.
    d. Because regression models did not attribute positive savings to other measures, their CCE costs are negative.

RECOMMENDATIONS

The Ouachita Electric Cooperative HELP program is generating higher savings for participants with higher prior usage. A straight forward approach to improve program performance would be to focus more resources on homes with higher usage. This study could be leveraged to establish program guidelines to direct resources to participants that will achieve higher average savings, and to reduce the resources budgeted for participants that will achieve lower average savings. This could involve strategies for identifying participants with high savings potential, and low savings potential, to direct resources appropriately.

In addition, packages of improvements that will improve the cost effectiveness for each group could be designed. For example, a lower cost package of measures may improve the cost effectiveness for participants with low prior usage. In particular, additional examination of the low savings results for the duct and LED measures may indicate when these measures lose effectiveness, resulting in improved program performance.

If not already in the program design, installing only high efficiency systems for HVAC measures should be evaluated, as these upgrades may be cost effective. However, note that the focus in this program on replacing HVAC systems with high efficiency heat pumps has resulted in reduced effectiveness of the duct measure, since duct losses are less costly with a high efficiency HVAC system.

Additional electric baseload savings could be achieved with selective replacement of older refrigerators. Refrigerator replacement can yield cost effective kWh per year savings when the age of the existing appliance or a watt meter is used to assess the load of the current unit. For example, installing an Energy Star refrigerator is estimated to save an average of 300 kWh when replacing a refrigerator made in 2000, 600 kWh when replacing one made in 1990, and 1,400 kWh per year when replacing one made in 1980.

1. DATA AND METHODOLOGY

MEASURES ANALYZED

The Ouachita HELP Program provides energy savings upgrades to co-op members. The measures recorded in the 2016 data include:

- Energy audits to identify improvements for energy savings, and address health and safety issues including combustion air, venting bath fans, and venting dryers.
- Furnace safety inspection and tune ups as needed.
- Furnace replacement with high efficiency heat pumps to switch from propane or wood to electric heating.
- Upgrades of existing heat pumps to more efficient models when indicated.
- Blower door testing, envelope air sealing to reduce infiltration identified by blower door testing, and blower door testing after sealing to confirm that the infiltration reduction target has been met.
- Duct blaster testing, and duct system sealing when indicated by duct blaster testing.
- Replacement of incandescent and CFL lights with LEDs.
- Insulation of attic and knee walls when poorly insulated.

An average of $5,634 per house was spent on the 198 houses in the program.

DATA SOURCES

This study is limited to data provided for 198 homes improved during the study period, May 25, 2016 and February 20, 2017. These data were provided in several files containing detailed electric billing information before and after improvements were completed, and program participant data:

- Electric usage data were collected from Ouachita Electric Cooperative for one year of bills before and after the improvements were completed on each house.
- Program data for the participating homes, including information about the condition of the home before and after improvements, cost of improvements, and the HVAC and weatherization contractors implementing the improvements.
- Two weather databases were used, one for average weather and one for weather concurrent with utility bills. Weather data are extracted that matches the location and time period of utility bills for each house. Additional details are provided in the Appendix.

METHODOLOGY FOR ANALYZING ENERGY SAVINGS

The analysis of savings followed the International Performance Measurement & Verification Protocol[1], including the following steps:

- Cleaning the utility data and identifying one year periods for pre- and post-improvement bills based on the implementation dates for each house provided in the program database;
- Calculating weather normalized annual usage based on the pre and post-implementation utility bills. Details of the analysis are provided in the Appendix.
- Analyzing the pre and post usage, and resulting savings estimates for subsets of the participants, including regression analysis of the impact of measures and contractors on savings, and adjustment of gross to savings to savings net of the change in usage experienced by the comparator group during the study period.

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[1] *International Performance Measurement & Verification Protocol - Volume I (*DOE/GO-102002-1554; March 2002); *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*, Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol (NREL/SR-7A30-53827; April 2013).

The analysis focused on estimating the electric savings of participant homes. Improvements included “fuel switching” in some homes where heat pumps were installed in homes that were previously heated by propane or wood. Switching heating loads to electric results in increased electrical use, even though the heat pump provides a more comfortable, efficient and economical alternative. Therefore the analysis deals with fuel switching homes separately.

Improvements in participant homes were completed between May 25, 2016 and February 20, 2017. The analysis of savings was adjusted for changes in usage experienced by a non-participant comparator group before and after this implementation period, as described in the Appendix.

Additional details on methodology can be found in Appendix.

2. HOMES TREATED BY MEASURE

During the study period, 233 homes participated in the program. Table 1 lists the number and percent of participants receiving each measure, and the average cost. These values are reported for all participants, and separately for the 73 homes that had sufficient data to produce estimates of savings. See the Appendix section on attrition for an explanation of the reasons that some participants were not included in savings estimates.

TABLE 1: MEASURES FOR ALL PARTICIPANTS VS. THOSE WITH SAVINGS ESTIMATES

Participants	Air Sealing	Duct Sealing	LED	Insulation	HVAC	Total
All Participants	183	148	175	156	159	198
% of Group	92%	75%	88%	79%	80%	100%
Average Cost	$540	$454	$92	$804	$3,949	$5,634
Have Savings Results	64	44	58	49	51	71
% of Group	90%	62%	82%	69%	72%	100%
Average Cost	$626	$355	$111	$932	$4,030	$5,773

The remainder of this report deals exclusively with the group of homes that produced estimates of savings. Therefore it is valuable to compare the measures implemented for these homes, versus all participating homes.

Table 1 shows that fewer homes with savings received every measure. The most common measure, air sealing, was implemented for 92% of all participants, versus 90% of homes included in savings estimates. LEDs were installed in 88% for all homes versus 82% of homes with savings, making this the second most common measure. HVAC and insulation measures are implemented in 80% for all homes versus 72% of homes with savings. Duct sealing was implemented in 75% of all homes versus 62% of homes with savings, making it the least common measure. Though fewer of the homes with savings received each measure, the order of measures by frequency is the same: air sealing, LED, HVAC, insulation, duct sealing.

Average cost of measures per home were similar for each group. The total cost averaged $5,634 for all participants, and $5,773 for homes with savings estimates. HVAC measures are by far the most expensive, averaging over $3,900 per home, and consuming over two-thirds of total costs.

Though the homes with savings can be considered representative of all participating homes, there are consistent differences in terms of the measures they received. These homes received fewer improvement measures than all participants. For example, the most common package of improvements, including all measures, was provided to 48% of all homes, but only 26% of homes providing savings estimates. Every measure was provided in lower percentages to homes that were included in savings estimates. Since the group of homes included in savings estimates received consistently fewer measures, when data are available to compute savings estimates for all participants, higher savings could be observed.

The participants included 4 apartments, and 6 homes where the HVAC measure resulted in fuel switching. The apartments were included in the estimates of savings, but the fuel switching homes were treated separately, since fuel switching necessarily results in increased electric usage.

3. ELECTRIC SAVINGS

Savings analyses were conducted for single family homes and apartments. Of the 198 homes in the program, 65 non-fuel-switch homes had sufficient data to be included in the savings analysis (see Appendix section on Attrition for details). Table 2 summarizes overall usage and estimates of savings. Table 2 reports that weather-normalized annual usage was computed for 65 participants before and after measures were implemented. These homes had an average electric usage of 16,263 kWh before improvements and 12,669 kWh after improvements, resulting in gross savings of 3,593 kWh.

The comparator group of 28 homes had a small savings of 53 kWh, resulting in a small decrease in net savings for the participant group from 22.1% to 21.8%. The comparator group also had 31% higher usage than the participant group, raising the concern that the comparator group is differs in ways other than participation from the participant group.

The use of the comparator group savings to compute net savings for participants assumes that the comparator group savings represent savings the participant group would have experienced in the absence of improvements. The figures in parentheses represent the 90% confidence interval for the average savings. Average net savings, and the confidence interval, are computed by subtracting the savings for the comparator group from the gross savings for participants.

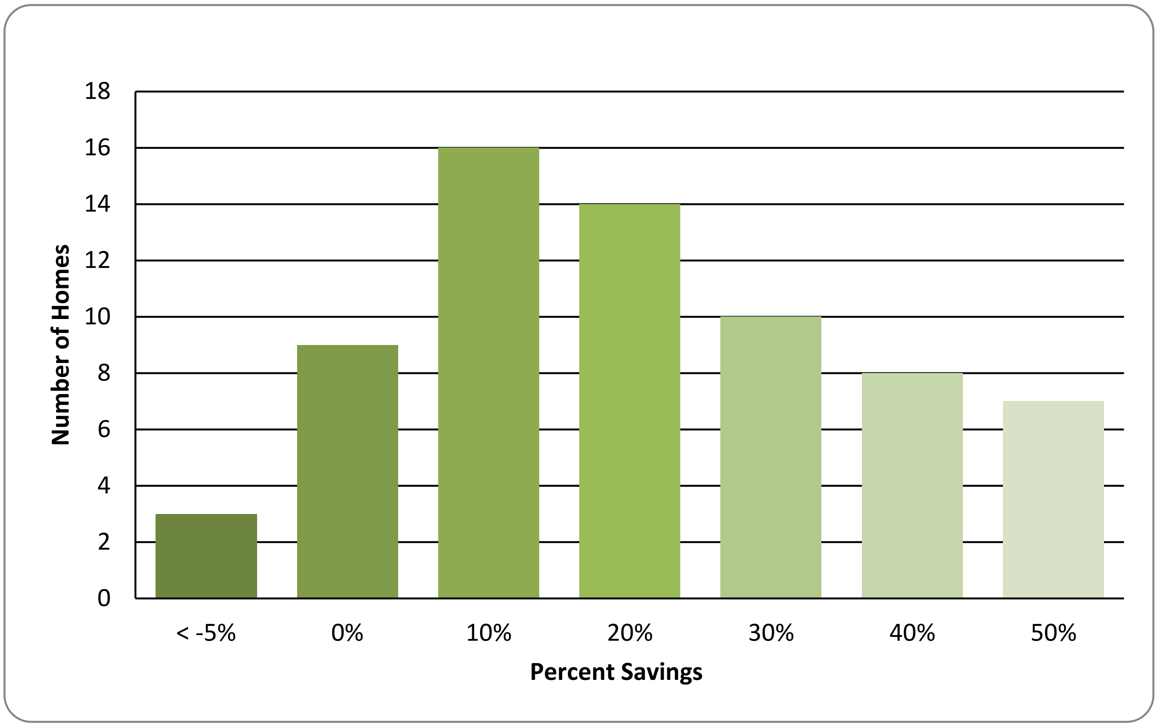
TABLE 2: ELECTRIC USAGE & SAVINGS RESULTS (KWH/YR)

Group	Count	Usage (kWh)		Savings (kWh)		% Savings	
		Pre	Post	Gross	Net	Gross	Net
Non-Fuel Switching Participants	65	16,263	12,669	3,593	3,540 (±1,341)	22.1%	21.8% (±8.2%)
Comparators	28	21,323	21,269	53		0.25%	

VARIATIONS IN SAVINGS

The average savings reflect the overall success of the program in reducing electric usage, but participating houses experience a wide range of savings. The patterns of savings provide insights into factors affecting savings that can inform program evaluation. Figure 1 shows the percent savings distribution. The number of homes experiencing a level of savings increases to a peak at 5-15%, and then decreases as savings increase. Most homes, 60%, realize savings between 5% and 35%.

FIGURE 1: DISRIBUTION OF GROSS % SAVINGS



SAVINGS VERSUS USAGE BEFORE IMPROVEMENTS

Table 3 shows the results of the gross savings analysis for both pre and post-improvement usage. Net savings results are not computed since net adjustments would require a comparator group that matched each level of usage, and the number of comparators is too small to be subdivided and still provide a statistically meaningful adjustment.

Table 3 shows that the 16 homes with the lowest usages, less than 10,000 kWh per year, saved on average the least: 1,214 kWh, which represented a 17% savings. With one exception, the group of homes with the largest pre-improvement usage, 30,000-35,000 kWh, saved the most, an average of 10,411 kWh per year.

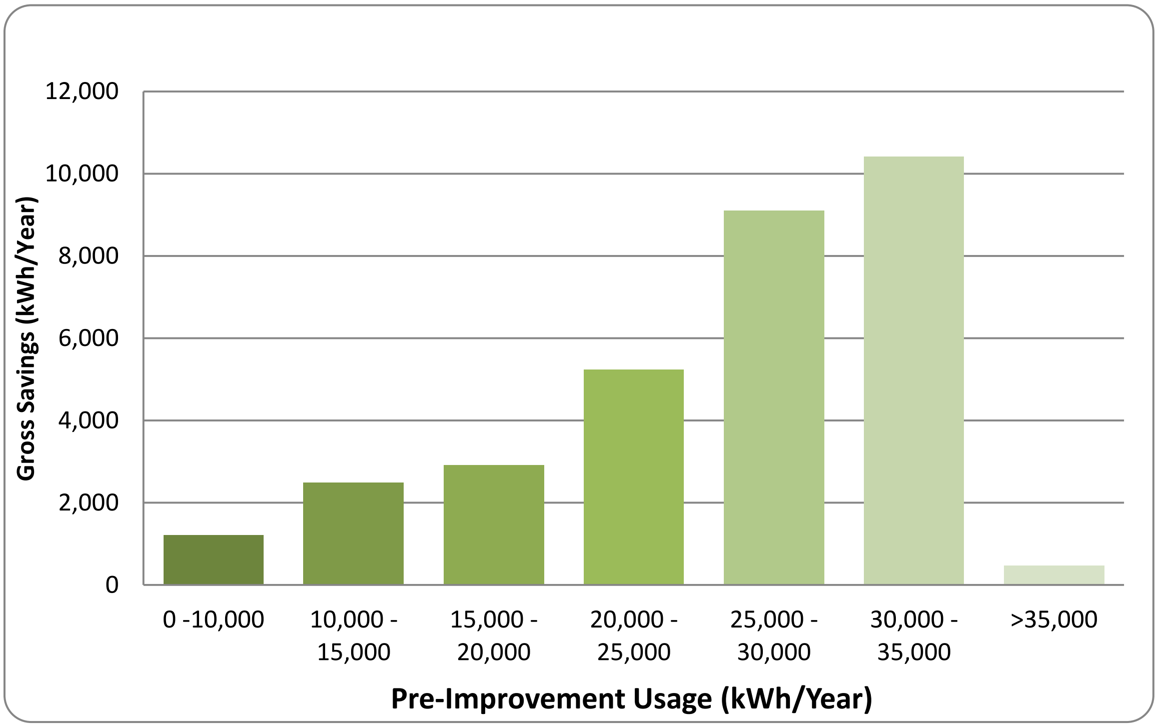
TABLE 3: SAVINGS BY LEVEL OF PRIOR USAGE (NON-FUEL SWITCHING)

Prior Usage (kWh/Year)	Cases	Prior Use	Post Use	Gross Save	Gross % Save	Net Save	Net % Save
0 -10,000	16	6,942	5,729	1,214	17%	1,161 (±1,269)	16.7% (±18.3%)
10,000 -15,000	14	12,316	9,835	2,481	20%	2,428 (±1,336)	19.7% (±10.8%)
15,000 -20,000	14	17,333	14,424	2,909	17%	2,856 (±1,472)	16.5% (±8.5%)
20,000 -25,000	12	21,916	16,683	5,232	24%	5,179 (±1,903)	23.6% (±8.7%)
25,000 -30,000	6	27,270	18,168	9,102	33%	9,049 (±3,108)	33.2% (±11.4%)
30,000 -35,000	2	33,078	22,666	10,411	31%	10,358 (±14,146	31.3% (±42.8%)
>35,000	1	38,161	37,689	473	1%	419 (± NA)	1.1% (± NA)
Total	65	16,263	12,669	3,593	22%	3,540 (±1,341)	21.8% (±8.2%)

This table illustrates the increase in savings as pre-weatherization usage increases. The percent savings also tends to increase as usages increases, but this pattern is not uniform, especially for the one home with the highest usage, reinforcing the observation that pre-improvement usage is an important predictor of savings.

Figure 2 shows the same pattern of increasing savings with increasing pre-improvement usage. The trend is consistent, except for the home with the largest pre-improvement usage, which saved only 1% after improvements.

FIGURE 2: GROSS SAVING BY PRIOR USAGE



IMPROVEMENTS IMPLEMENTED BY PRIOR USAGE

In addition to savings, the resources invested in improvements is influenced by prior usage. As prior usage increases, the total cost of improvements increases. Figure 3 shows this pattern, though it is not as consistent as the increase in savings with increasing pre-improvement usage. The only marked contradiction to this pattern is in the home with the highest usage, represented by the bar on the right of Figure 3. The improvement costs for this house were relatively low because two of the main improvements were not included. This helps explain the anomalously low savings in this home noted in the last section.

FIGURE 3: TOTAL IMPROVEMENT COST BY PRIOR USAGE

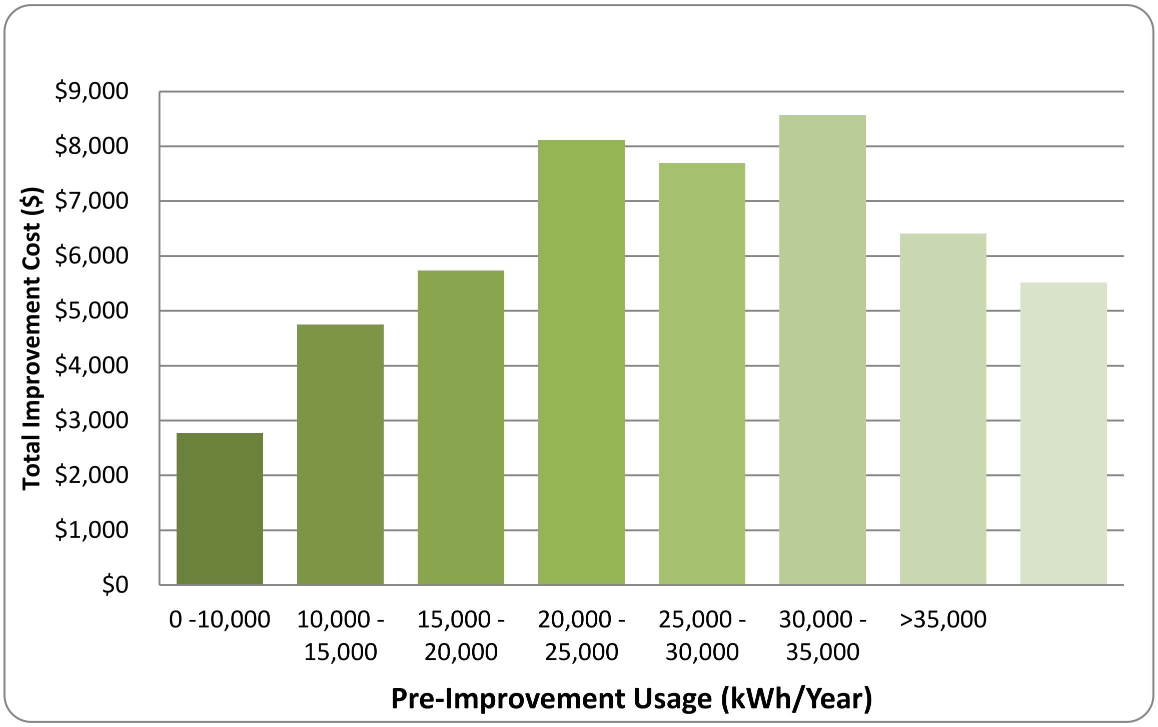


Table 4 shows the total cost of improvements by prior usage, and the percentage of homes receiving each of the measures. Overall, most improvements are implemented on a high proportion of homes in each usage group. The most consistently applied improvement is air sealing. This is supported by the finding in the next section that the air sealing measure produces the most savings.

TABLE 4: MEASURES AND COST BY PRIOR USAGE

Prior Usage (kWh/Year)	Cases	Cost	Air Seal	Duct	LED	Insulate	HVAC
0 -10,000	16	$2,768	94%	38%	88%	94%	19%
10,000 -15,000	14	$4,753	86%	79%	79%	71%	79%
15,000 -20,000	14	$5,733	86%	71%	79%	64%	79%
20,000 -25,000	12	$8,112	100%	58%	83%	50%	92%
25,000 -30,000	6	$7,690	100%	67%	83%	50%	100%
30,000 -35,000	2	$8,568	100%	100%	100%	100%	100%
>35,000	1	$6,407	100%	0%	100%	0%	100%
All Non-Fuel Switching	65	$5,509	92%	62%	83%	69%	69%

SAVINGS AND MEASURES FOR APARTMENTS VERSUS SINGLE-FAMILY HOMES

Table 5 reports the average annual pre and post usage, and savings for apartments compared to single-family homes. Apartments exhibit lower usage than single family homes, as is typical. Apartments exhibit a higher average percentage savings, however, which is remarkable given their lower initial usage. However, the significance of any comparison by residence type is limited because the number of apartments is so small (4) that the averages are not a reliable reflection of the results for that residence type. Most of the apartment participants had insufficient utility data, so a follow up analysis with more recent date would yield many more results for apartments.

TABLE 5: USAGE AND SAVINGS BY APARTMENT VS. SINGLE FAMILY HOMES

Residence Type	Cases	Prior Use (kWh)	Post Use (kWh)	Gross Save (kWh)	Gross % Save
Single-Family	61	16,751	13,059	3,691	22.0%
Apartment	4	8,825	6,726	2,099	23.8%
All Non-Fuel Switching	65	16,263	12,669	3,593	22.1%

Table 6 compares the program costs, and frequency of measures for apartments and single-family homes. Apartments show lower cost, and different rates of implementing measures, but again, the number of apartments is too small to indicate that differences are due to residence type rather than chance variation.

TABLE 6: MEASURES AND COST BY APARTMENT VS. SINGLE FAMILY HOMES

Residence Type	Cases	Cost	Air Seal	Duct	LED	Insulate	HVAC
Single-Family	61	$5,556	93%	62%	82%	67%	67%
Apartment	4	$4,797	75%	50%	100%	100%	100%
All Non-Fuel Switching	65	$5,509	92%	62%	83%	69%	69%

SAVINGS AND MEASURES FOR FUEL SWITCHING HOMES

Table 7 reports the average annual pre and post usage, and savings for fuel switching homes, compared to all other participants, and results when they are combined with other participants. Fuel switching homes exhibit lower usage than single family homes, as is typical. Fuel switching homes exhibit pre-improvement electric usage (18,101 kWh/year) that is similar to that for other homes (16,263 kWh/year).

However, fuel switching homes also had significant fuel usage for heating prior to the fuel switching improvements. This prior fuel usage is converted from therms to an average of 12,497 kWh/year.[2] The total of electric and fuel prior usage is reflected in the second row of Table 7 (18,1010 + 12,497 = 30,598). Based on this level of prior usage, fuel switching homes saved an average of 11,959 kWh, or 39.1%.

The last row of Table 7 shows the estimate of program savings when the 39.1% savings from fuel switching homes is included. This raises the estimated program savings from 22.1% to 24.6.%, as shown in the last row of Table 7.

TABLE 7: USAGE AND SAVINGS FOR FUEL SWITCHING HOMES

Project Type	Cases	Prior Use (kWh)	Post Use (kWh)	Gross Save	Gross % Save
Fuel Switching: Electric Only	6	18,101	18,639	-538	-3.0%
Fuel Switching: Electric+Fuel	6	30,598	18,639	11,959	39.1%
Non-Fuel Switching	65	16,263	12,669	3,593	22.1%
Add Fuel Switching: Electric+Fuel	71	17,474	13,174	4,300	24.6%

Table 8 compares the program costs, and frequency of measures for fuel switching versus other participants. Fuel switching homes show higher average cost, and lower rates of non-heating system improvements: air sealing, insulation and LED improvements. As would be expected, since fuel switching involves installing new heat pumps, fuel switching projects have higher rates of system-related improvements (ducts and HVAC).

TABLE 8: MEASURES AND COST FOR FUEL SWITCHING HOMES

Project Type	Cases	Cost	Air Seal	Duct	LED	Insulate	HVAC
Fuel Switching	6	$8,631	67%	67%	67%	67%	100%
Other Participants	65	$5,509	92%	62%	83%	69%	69%
All Participants	71	$5,773	90%	62%	82%	69%	72%

[2] Conversion from fuel to electric usage is based on site consumption. No information was available to convert based on source consumption (i.e. usage for electrical generation). Only annual usage estimates were available for prior fuel usage, so no weather normalization was possible.

SAVINGS BY MAJOR IMPROVEMENTS

This program implemented most improvements together, typically implementing the complete package of improvements, or implementing all but one measure. This pattern, together with the small number of participants with measured savings, results in limited information about the savings provided by each measure. The groups of participants receiving different packages are too small to provide valid comparisons, so usage comparisons by package of improvements will not be presented.

A multivariate regression analysis was conducted which provides an estimate of the savings attributable to each measure. The results are reported in Table 9. Air sealing and HVAC resulted in the greatest savings, generally two to three times the saving of other measures. Also notable is the very low or negative estimated contribution of duct and LED measures.

TABLE 9: REGRESSION ESTIMATE OF SAVINGS BY MEASURE (KWH/YEAR)

Participants	Air Seal	Ducts	LED	Insulate	HVAC	Total
Non-Fuel Switching	2,264	-63	-1,137	771	2,826	3,593
+ Fuel Switching: Electric Only	2,846	-254	-1,049	342	2,075	3,244
+ Fuel Switching: Electric+Fuel	1,741	-63	-1,031	980	3,464	4,300

HVAC coefficient statistically significant at the 0.01 for Non-Fuel Switching, 0.05 level other models; Air Sealing statistically significant at the 0.05 level in the + Fuel Switching: Electric Only model.

The contributions to savings were statistically significant for two measures: air sealing and HVAC replacement. These were the measures with the largest savings, together representing most of the total savings.

SAVINGS BY HVAC CONTRACTOR AND WEATHERIZATION CONTRACTOR

A multivariate regression analysis was conducted to determine whether the HVAC or weatherization contractor preforming the improvements impacted the level of savings. The results did not indicate any difference between contractors, in part because the number of cases for each contractor was small, and because there are large variations between individual participant savings. However, the lack of a detectable difference between contractors also indicates that savings were similar across contractors, because large enough differences in performance would have been detected even with the small sample size and high variability.

4. COST EFFECTIVENESS

Common cost-effectiveness analysis compares the net present value of program energy savings to program costs. A variety of methods for assessing benefits are employed to address the perspective of different stake holders. For the home-owner, benefit is typically based on utility bill savings, based on retail rates, and possibly other benefits that are not reflected in reduced bills. For programs funded by utilities, some version of the Total Resource Cost test (TRC) is often applied, which assesses benefits based on avoided cost.

For this report, given that only retail electric rates have been provided, a savings to investment ratio (SIR) is computed, using current retail rates. The SIR is the ratio of the present value of costs of the program, to the present value of future savings. To avoid making assumption of the escalation rate of utility rates, rates are assumed to increase at the discount rate, resulting in a net-zero impact of cost escalation and present valuation. This results in a SIR that is the same as the ratio of the measure lifetime to the simple payback years.

The current electric utility rate is $0.0985 per kWh for all participants, exclusive of taxes and delivery fees. When those are added the total utility rate varies, ranging by county from $0.12 to $0.16 per kWh. Using these costs, and a net-zero impact of utility rate escalation and discounting, the SIR for this program ranges from 1.54 to 2.57.

An alternative cost effectiveness metric that does not require assumptions about the future cost of electricity is the levelized Cost of Conserved Energy (CCE). CCE computes the net present value of the costs versus savings from the program.[3] The CCE calculates the sum of the annual discounted costs of the program, and divides that by the annual discounted savings over the lifetime of the measures. Instead of a benefit-cost ratio, CCE is a method of evaluating the cost of energy saved over the lifetime of the improvements, or, in other words, the value of future energy saved which would recoup the program cost. To calculate the CCE an average measure lifetime of 20 years is used and a discount rate of 3%, referred to as the time value of money.

Table 10 reports the results of the CCE analysis. The levelized costs of saved energy for the program ranges from $0.090 to $0.120 per kWh, depending on how fuel switching homes are treated. Without fuel switching homes, the levelized cost is $0.103 per kWh saved.

[3] See for example p. 36ff in *A Tool to Prioritize Energy Efficiency Investments*, Philip Farese, Rachel Gelman, and Robert Hendron, National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-54799 , August 2012.

TABLE 10: COST OF CONSERVED ENERGY BY MEASURE (KWH/YEAR)

Participants	Air Seal	Ducts	LED	Insulate	HVAC	Total
Non-Fuel Switching	$0.019	-$0.384	-$0.007	$0.079	$0.089	$0.103
+ Fuel Switching: Electric Only	$0.015	-$0.094	-$0.007	$0.183	$0.131	$0.120
+ Fuel Switching: Electric+Fuel	$0.024	-$0.378	-$0.007	$0.064	$0.078	$0.090

The negative savings for ducts and LED measures do not indicate that these measures reduced savings, but that their inclusion in the regression model tended to lower the savings from other measures. This type of effect is supported by the interaction between measures which tends to reduce the savings that would be realized from each measure individually, when measures are combined. This result in the regression model is less surprising in this case, where ducts and LED measures are never implemented without other measures.

5. CONCLUSIONS AND RECOMMENDATIONS

The Ouachita Electric Cooperative HELP program is generating savings of about over 3,500 kWh per year per participant, which represents a savings of 22% of prior usage. The program is exceeding the anticipated level of savings. As expected, participants with higher prior usage achieved higher average savings. Therefore participants with lower prior usage tend to lower program savings. A straight forward approach to improve program performance would be to focus more resources on homes with higher usage.

This study could be leveraged to establish program guidelines to direct resources to participants that will achieve higher average savings, and to reduce the resources budgeted for participants that will achieve lower average savings. This could involve strategies for identifying participants with high savings potential, and low savings potential, to direct resources appropriately.

In addition, packages of improvements that will improve the cost effectiveness for each group could be designed. For example, a lower cost package of measures may improve the cost effectiveness for participants with low prior usage. In particular, additional examination of the low savings results for the duct and LED measures may indicate when these measures lose effectiveness, resulting in improved program performance.

If not already in the program design, installing only high efficiency systems for HVAC measures should be evaluated, as these upgrades may be cost effective. However, note that the focus in this program on replacing HVAC systems with high efficiency heat pumps has resulted in reduced effectiveness of the duct measure, since duct losses are less costly with a high efficiency HVAC system.

Additional electric baseload savings could be achieved with selective replacement of older refrigerators. Refrigerator replacement can yield cost effective kWh per year savings when the age of the existing appliance or a watt meter is used to assess the load of the current unit. For example, installing an Energy Star refrigerator is estimated to save an average of 300 kWh when replacing a refrigerator made in 2000, 600 kWh when replacing one made in 1990, and 1,400 kWh per year when replacing one made in 1980.

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1. International Performance Measurement & Verification Protocol - Volume I (DOE/GO-102002-1554; March 2002).
2. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol (NREL/SR-7A30-53827; April 2013).
3. *Inverse Modeling Toolkit: Numerical Algorithms*, John Kissock, Jeff Haberl and David Claridge, [KC-03-2-1 (RP-1050)]

APPENDIX

DATA COLLECTION & PREPARATION

Primary data used in this analysis come from the Ouachita Electric Cooperative, and the program implementer, EEtility. Ouachita Electric Cooperative provided utility records, and EEtility provided data on program implementation, including measures, cost and completion dates for all participants.

Data were prepared by matching utility data for each participant for the year before and at least 10 months of data after measures were implemented. Data were also gathered to indicate prior fuel usage for fuel switching participants. Erroneous data were identified in this phase, as well as throughout the analysis by anomalous results.

The evaluation assessed electric savings of participants treated during the study period, May 25, 2016 and February 20, 2017. The data were provided in several files containing detailed electric billing information before and after improvements were completed, and program participant data:

- Electric usage data were collected from Ouachita Electric Cooperative for one year of bills before and after the improvements were completed on each house.
- Program data for the participating homes, including information about the condition of the home before and after improvements, cost of improvements, and the HVAC and weatherization contractors implementing the improvements.
- Two weather databases were used, one for average weather and one for weather concurrent with utility bills. Weather data are extracted that matches the location and time period of utility bills for each house.

The analysis involved these steps:

- Cleaning the usage data and identifying approximately year long periods of meter readings pre and post program implementation dates;
- Computing the normalized annual consumption (NAC) using the PRISM weather-normalization method.
- Combining the pre and post implementation NAC to compute savings for each participant. Data Collection

Assembling the required data required substantial effort as is typical. The data collection, cleaning, and analysis process included many steps to identify, correct or eliminate data inaccuracies or anomalies.

COMPARATOR DATA

Comparators are required to estimate any exogenous, or non-program-related, change in average usage during the study period. If savings are not adjusted for the savings experienced by a comparison group, savings estimates will be biased if factors outside the program affected energy use. For example, an increase in the utility prices might depress usage.

Comparators should be representative of the program participants. Ideally they would mirror the participants in demographics, type of housing, energy usage, and other factors affecting energy use, except that they would not be program participants. The sample of comparators in this analysis was too small to match the comparators with participants, so comparators were selected from future participants to increase the likelihood that they would be representative of participants.

Utility data were provided by Ouachita for 30 non-participants for a 36 months period. The adjustment of gross to net savings is conducted to remove any non-program changes in average usage during the program period. Program participants had the following distribution of starting months:

- 5/1/2015: 7
- 6/1/2015: 9
- 7/1/2015: 8
- 8/1/2015: 11
- 9/1/2015: 12
- 10/1/2015: 10
- 11/1/2015: 8
- 12/1/2015: 4
- 1/1/2016: 7
- 2/1/2016: 1

Given this distribution of program participation, changes in weather normalized usage was computed for each comparator using one year of prior, and one year of post data, in three staggered 24-month periods. These periods started on 5/1/2015, 9/1/2015, and 12/1/2015.

Of the comparators, 29 had sufficient utility bills to complete the weather normalized usage analysis. Changes in weather normalized annual usage were computed for the three 24-month periods identified above. One of the comparators did not pass the normalized mean bias error required, and was eliminated, leaving 28 comparator results. These results were used to compute the comparator gross savings and related 90% confidence interval. Comparator data were cleaned and analyzed in the same way as data for participants.

ATTRITION ANALYSIS

As mentioned in the Summary of Findings, and detailed in Table 1, only 73 of the 198 program participants had sufficient utility data of adequate quality to produce estimates of weather normalized savings. The process of losing participants from the sample used in the study because of data inadequacies is called attrition. Table 11 summarizes the stages of data preparation and analysis that resulted in sample attrition.

TABLE 11: PARTICIPANT ATTRITION

Reason Participant Lost for Savings Estimates	Count
All cases	198
Total not electric heat	
Insufficient utility data	116
Bill period 40+ days (possible faulty data or unoccupied period)	4
Poor fit regression to data (NMBE>5%)	5
Total insufficient data	
Total bad fit	
Total outliers	
Good cases	73 (36.9%)

This table illustrates that there were 198 participants in the data, and that of those 116 had insufficient utility data, four had bill periods that longer than the normal monthly period, and five cases failed to provide a sufficiently reliable regression result, leaving the 73 cases that are analyzed in this report.

Sample attrition is often problematic in this type of analysis. Attrition is often so extreme that only a small number of participants have adequate data to support an estimate of savings. This may be true even if relaxed criteria are used in screening participant data. To minimize the impact of attrition, efforts are made in this study to retain as much of the sample as possible to minimize the tendency for the sample to be unrepresentative in the presence of significant attrition.

This evaluation uses the most relaxed data requirements possible, while still supporting reliable estimates of NAC. Electric usage regression analysis results were reviewed for quality, removing cases with the following quality issues:

- Insufficient utility data: fewer than 365 days of usage data, unless the following conditions were met:
    - Data span at least 330 days OR span more than 183 days and the following:
        - If fuel provides heating:
            - total HDDs in time span > 0.5 * $HDD$65;
            - at least one period with HDD/day < 0.2 * $HDD$65 /365;
            - at least one period with HDD/day > 1.2 * $HDD$65 /365.
        - If fuel provides cooling:
            - total CDDs in time span > 0.5 * $CDD$65;
            - at least one period with CDD/day < 0.2 * $CDD$65/365;
            - at least one period with CDD/day > 1.2 * $CDD$65/365.
    - Have a regression analysis Coefficient of Variation of the Root Mean Square Error (CVRMSE) <= 20%
- Unusually long bill periods: length of 40 days or more, indicating a gap in data;
- Large regression error: net mean bias error (NMBE) greater than 5%.

Substantial attrition was lower in this study than is typical in this type of study. However, sample attrition could be reduced even further by the following:

- Data collection anticipating the analysis, so that utility and program data sufficient for the study are collected and verified contemporaneously;
- Utility data delivery included a longer historical period than the minimum required for the study, Specifically the data should allow for selection of uniform time periods across all participant data;
- Utility data included zip codes to geolocate the home more accurately to facilitate matching with weather data;
- Data delivery include all available cases, rather than being culled to match the minimum requested for the study;
- Program tracking data included more accurate prior fuel usage to evaluate the impact of fuel switching.

Attrition not only reduces the size of the sample on which the analysis is based, but can also bias the sample if the participants remaining after attrition are not representative of all participants in terms of energy savings. One characteristic of participants that is known to affect savings is prior usage, so it would be advisable to compare prior use for participants in the study group versus all participants, to verify that the study group had a representative distribution of prior usage. However, utility data for participants did not cover a common pre-improvement period for all participants, so this comparison was not possible.

Table 1 demonstrated that the measures implemented for all participants versus those left after attrition were similar, so they could be considered representative of all participating homes. However, there are consistent differences in terms of the measures received. The remaining homes received fewer improvement measures than all participants. For example, the most common package of improvements, including all measures, was provided to 48% of all homes, but only 25% of homes providing savings estimates. Every measure was provided in lower percentages to homes that were included in savings estimates. Since the group of homes included in savings estimates received consistently fewer measures, when data are available to compute savings estimates for all participants, higher savings could be observed.

ENERGY SAVINGS ANALYTIC METHOD

INTERNATIONAL PROTOCOL

OptiMiser implements the evaluation of realized savings specified in the Uniform Method Protocol for Whole Building Energy Retrofit.[4] OptiMiser calculates savings for each building based on weather-normalized annual consumption (NAC). This standard is designed to address evaluation conditions that occur with a whole-house retrofit program. The key reasons for using this method are:

- The goal of the program is improvement of whole-house performance;
- Because multiple different measures are installed, the individual savings of each cannot be easily isolated because of interactive effects;
- The expected savings are large enough to be discernible over natural variation in the consumption data, at least across the aggregate of program participants.

OptiMiser uses the recommended Two-Stage Approach, when (1) data is available for a valid comparison group and (2) sufficient consumption data is available for each building in the analysis. The two-stage method proceeds in two stages:

- Stage 1: Weather-normalized annual consumption (NAC) is estimated separately for each building in the analysis for both the pre- and post-program periods.
- Stage 2: A cross-sectional analysis is conducted on the NAC results from Stage 1 to estimate program-related savings.

[4] *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*, Chapter 8.

NAC PRISM REGRESSION ANALYSIS

The OptiMiser modeling program was used to compute NAC, including generating statistical evaluation of the NAC regression model. The before and after utility bills were used to measure actual savings. A PRISM variable base degree day model was used to identify the best-fit heating and cooling base temperature per the *Inverse Modeling Toolkit: Numerical Algorithms*.[5]

Analysis of these data were automated through the OptiMiser program, using the following procedure:

- Check utility data to identify twelve months of before and after utility records as close to the improvement completion as possible, and merging this utility data with project data.
- Develop a system to automate the OptiMiser analysis of each project.
- Collect data from the OptiMiser analysis which includes.
  - Computation of the Weather normalized usage before improvements.
  - Calculation of a whether normalized usage after improvements.
  - OptiMiser predicted savings and SIR.
- Compare and analyze the pre and post improvement usage to calculate savings for each project.
- Conduct cross tabulation and regression analysis of savings results to determine savings rates for different levels of initial usage, different house types and improvements.

WEATHER DATA

Two weather databases are provided and are used for different functions in the program:

- 30-Year Weather Normals: 30-Year Weather Normals are provided by the National Climatic Data Center (NCDC) for 5,556 stations. Standard HDDs and CDDs are provided, as well as daily average temperatures which are used to compute variable base heating degree and cooling degree days.
- Current Weather: Current weather data drawn from the NCDC Quality Controlled Data (QCD) for over 1,000 sites are available in monthly downloadable files from the OptiMiser website. These data are used in utility calibration by comparing the heating and cooling degree days to utility bills during the same period to calibrate the base temperature for heating and cooling degree days.

[5] *Inverse Modeling Toolkit: Numerical Algorithms*, John Kissock, Jeff Haberl and David Claridge, [KC-03-2-1 (RP-1050)]

DEGREE DAY DATA

Standard HDDs and CDDs are provided with the 30-Year Weather Normals data. The daily average temperatures from this database are used to compute a variable base HDD and CDD using the optimal base temperature derived from the PRISM analysis. Both standard and optimal HDD and CDD values can be used in the energy modeling. The standard DD analysis will reflect accepted "asset" modeling, whereas the optimal DD analysis will more closely reflect the "occupant" energy use.