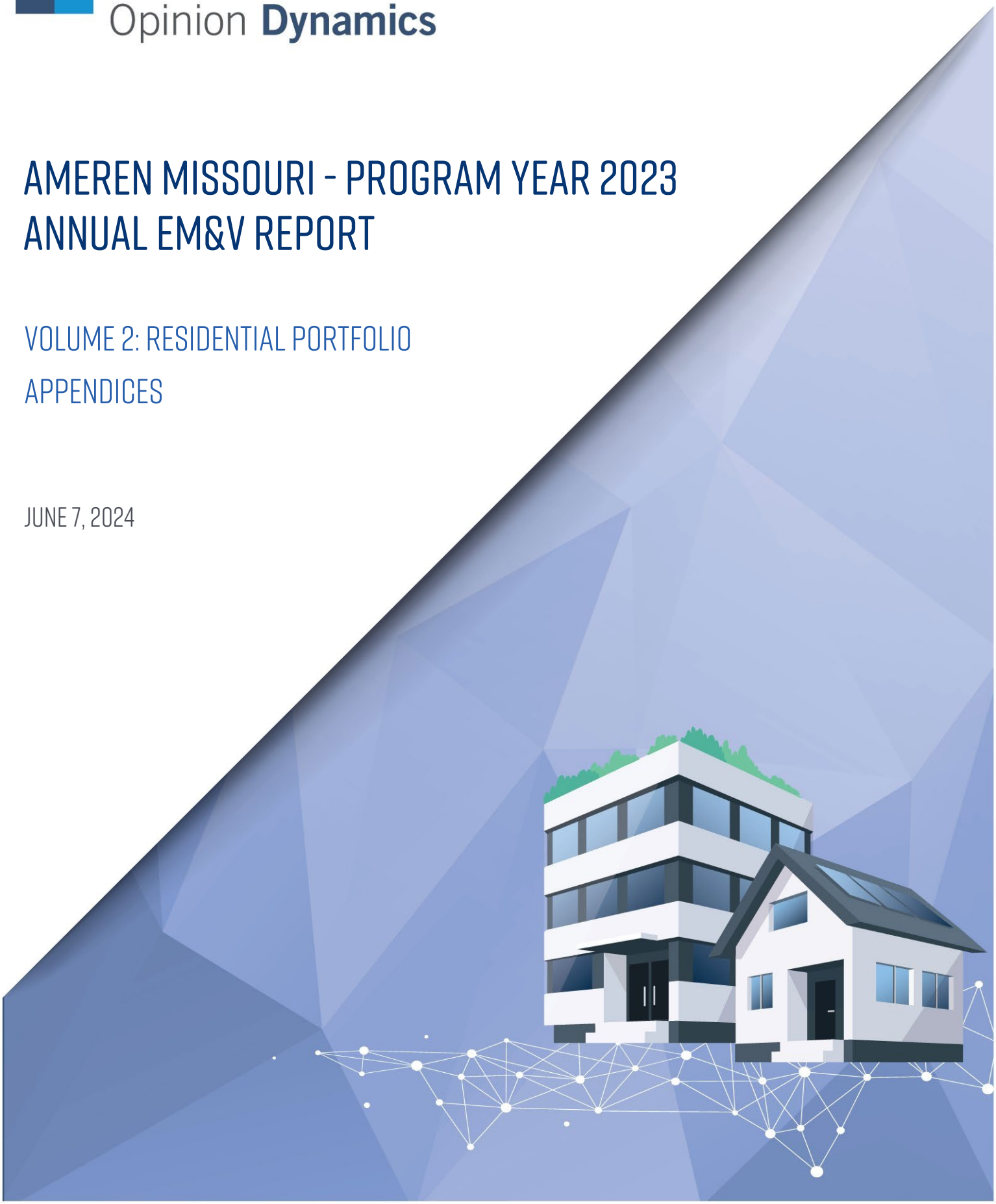
Opinion Dynamics

# AMEREN MISSOURI - PROGRAM YEAR 2023 ANNUAL EM&V REPORT

## VOLUME 2: RESIDENTIAL PORTFOLIO APPENDICES

JUNE 7, 2024



# CONTENTS



# TABLES & FIGURES

# APPENDIX A. DETAILED PRESCRIPTVE IMPACT ANALYSIS METHODOLOGY

The evaluation team estimated gross energy and demand savings for measures installed through residential and residential income eligible programs using prescriptive algorithms included in Version 6.0 of Ameren Missouri's technical reference manual (TRM) Appendix I and Appendix F. We applied a new baseline for applicable lighting measures installed on or after August 1, 2023 to align with the Energy Independence and Security Act (EISA) policy of a 45 lumens/watt efficiency. The EISA-compliant baseline wattages are reflected in Version 7.0 of the TRM (approved in November of 2023). Where available, our team used parameters included in tracking data collected by the implementation teams of each program and, where unavailable, deemed parameters included in the TRM. Table 1 includes references to the appropriate Missouri TRM appendix and section for each unique measure type offered through Ameren Missouri's suite of residential programs.[1]

Table 1. Missouri TRM Appendix Reference Table

| Measure Name | HVAC | REP | MFMR | PAYS Tier 1 | MFIE | SFIE | Community Lighting |
|---|---|---|---|---|---|---|---|
| Refrigerator Replacement | | | | | | Appendix F Income Eligible Appendix I 3.1.1 | |
| Advanced Power Strips Tier 1 | | Appendix F EE Kits Appendix I 3.2.1 | | Appendix F Income Eligible Appendix I 3.2.1 [A] | | | |
| Advanced Power Strips Tier 2 | | Appendix F REP Appendix I 3.2.2 | | | Appendix F Income Eligible Appendix I 3.2.2 | Appendix F Income Eligible Appendix I 3.2.2 | |
| Low-Flow Faucet Aerator | | | | Appendix F Income Eligible Appendix I 3.3.1 [A] | Appendix F Income Eligible Appendix I 3.3.1 | Appendix F Income Eligible and EE Kits Appendix I 3.3.1 | |
| Low-Flow Showerhead | | | | Appendix F Income Eligible Appendix I 3.3.2 [A] | Appendix F Income Eligible Appendix I 3.3.2 | Appendix F Income Eligible and EE Kits Appendix I 3.3.2 | |
| Water Heater Tank Wrap | | | | Appendix F Income Eligible Appendix I 3.3.3 [A] | | | |
| Heat Pump Water Heater | | Appendix F REP Appendix I 3.3.4 | Appendix F Efficient Products | | | | |

[1] Note that the evaluation team estimated ex post impacts for Tier 4 Pay As You Save (PAYS) Program measures using building energy modeling software and, as such, we reference our approach separately in Appendix C of this evaluation report.

| Measure Name | HVAC | REP | MFMR | PAYS Tier 1 | MFIE | SFIE | Community Lighting |
|---|---|---|---|---|---|---|---|
| | | | Appendix I 3.3.4 | | | | |
| Hot Water Pipe Insulation | | | | Appendix F Income Eligible Appendix I 3.3.5 [A] | | Appendix F Income Eligible and EE Kits Appendix I 3.3.5 | |
| Advanced Thermostat | Appendix F HVAC Appendix I 3.4.1 [A] | Appendix F REP Appendix I 3.4.1 | Appendix F Efficient Products Appendix I 3.4.1 | | Appendix F Income Eligible Appendix I 3.4.1 | Appendix F Income Eligible Appendix I 3.4.1 | |
| Air Source Heat Pumps | Appendix F HVAC Appendix I 3.4.2 [B] | | Appendix F HVAC Appendix I 3.4.2 | | Appendix F HVAC Appendix I 3.4.2 | Appendix F HVAC Appendix I 3.4.2 | |
| Duct Sealing | | | | | | Appendix F Income Eligible Appendix I 3.4.3 | |
| Ductless Minisplit | Appendix F HVAC Appendix I 3.4.4 [B] | | | | | | |
| Programmable Thermostat | | | | | Appendix F Income Eligible Appendix I 3.4.5 | Appendix F Income Eligible Appendix I 3.4.5 | |
| HVAC tune up | | | Appendix F MFMR Appendix I 3.4.6 | | Appendix F Income Eligible Appendix I 3.4.6 | Appendix F Income Eligible Appendix I 3.4.6 | |
| Electronically Commutated (Blower) Motor | | | Appendix F HVAC Appendix I 3.4.7 | | Appendix F Income Eligible Appendix I 3.4.7 | Appendix F Income Eligible Appendix I 3.4.7 | |
| Central Air Conditioner | Appendix F HVAC Appendix I 3.4.8 [B] | | Appendix F HVAC Appendix I 3.4.8 | | Appendix F HVAC Appendix I 3.4.8 | Appendix F HVAC Appendix I 3.4.8 | |
| Dirty Filter Alarm | | | Appendix F MFMR Appendix I 3.4.9 | | Appendix F Income Eligible Appendix I 3.4.9 | Appendix F Income Eligible and EE Kits Appendix I 3.4.9 | |
| Room Air Conditioner | | | | | | Appendix F Income Eligible | |

| Measure Name | HVAC | REP | MFMR | PAYS Tier 1 | MFIE | SFIE | Community Lighting |
|---|---|---|---|---|---|---|---|
| | | | | | | Appendix I 3.4.11 | |
| Ground Source Heat Pump | Appendix F HVAC Appendix I 3.4.12 [B] | | | | | | |
| Residential Lighting[D] | | | Appendix F MFMR Appendix I 3.5.1 and 3.5.2 | Appendix F Lighting Appendix I 3.5.1 and 3.5.2 [A] | Appendix F Income Eligible Appendix I 3.5.1 and 3.5.2 | Appendix F Income Eligible and EE Kits Appendix I 3.5.1 and 3.5.2 | Appendix F Lighting and Income Eligible Appendix I 3.5.1 and 3.5.2 |
| Business Lighting | | | Appendix F MFMR and BUS Appendix I 3.5.1 and 3.5.2 Appendix H 2.6.6 | | Appendix F Income Eligible and BUS 3.5.1 and 3.5.2 Appendix H 2.6.4 and 2.6.7 | | |
| Air Sealing | | | | | Appendix F Income Eligible Appendix I 3.7.1 | Appendix F Income Eligible Appendix I 3.7.1 | |
| Ceiling Insulation | | | | | Appendix F Income Eligible Appendix I 3.7.2 | Appendix F Income Eligible Appendix I 3.7.2 | |
| Motor Replacement | | | Appendix H 2.8.1 | | | | |
| VFD on Chilled Water Pump | | | Appendix H 2.8.5 | | | | |
| Window replacements | | | MO TRM 2017 2.12.1 [C] | | MO TRM 2017 2.12.1 [C] | | |

[A] The evaluation team applied in-service rates (ISR) developed from a participant survey that are different than those in the Ameren Missouri TRM.

[B] The evaluation team applied an early replacement ratio factor developed from a participant survey to account for inconsistencies in program tracking data.

[C] The evaluation team applied algorithms and assumptions from the Missouri Technical Reference Manual – 2017 – Volume 2: Commercial and Industrial Measures (dated March 31, 2017) Section 2.12.1 – Windows pp.27--284.

[D] For residential lighting measures, we applied a new baseline for applicable measures installed on or after August 1, 2023, to align with the Energy Independence and Security Act (EISA) policy of a 45 lumens/watt efficiency. The updated baselines are reflected in Version 7.0 of the TRM (approved in November of 2023).

# APPENDIX B. HEATING VENTILATION AND COOLING (HVAC)

## EARLY REPLACEMENT METHODOLOGY

The PY2023 evaluation used an operational/functional definition of early replacement (ER). The methodology is the same as that used in the PY2022 evaluation, but the ER data source for the PY2023 evaluation differs. While the PY2022 ER analysis relied on participant survey responses, the PY2023 analysis was able to leverage program-tracking data as the program implementer added the survey questions to the program's Terms and Conditions (T&C) Form in early 2023. The T&C Form captured the following information:

- Was the unit working/did it run when turned on, and, if so, did it meet the participant's cooling/heating needs?
- If not, was repair offered by the contractor?
- If so, was repair a feasible option for the participant?

The remainder of this section outlines the ER methodology applied in PY2023.

## TERMS AND CONDITIONS FORM QUESTIONS

Contractors provide the T&C Form to participants during installation and return the completed form to the program implementation team. While completion of the T&C Form and the new ER questions is encouraged, it is not mandatory.[2] All participants who installed a new central air conditioner or heat pump that replaced an existing central heating or cooling system and provided sufficient ER data on their T&C Form were included in the analysis. Blank forms or forms that were almost entirely blank were not included in the analysis.

The following three questions were included on the T&C Form:

ER1. Which of the following **best** describes the operating condition of the old unit that you replaced using an Ameren Missouri incentive? (*please select one*)

1. Unit ran when turned on and provided sufficient heating/cooling for my space
2. Unit ran when turned on but *did not* provide sufficient heating/cooling for my space (it worked but not well)
3. Unit did not run when turned on / it was not working

ER2. Did your contractor provide you with an option to repair your old unit?

1. Yes
2. No

[IF YES]

ER3. Why did you choose not to repair it?

1. Repair cost was too high to make feasible, so I/we did not consider repairing the unit
2. Repairs were a feasible option, but I/we decided to replace the unit instead
3. Other, please specify: [OPEN END]
98. Unsure
99. Blank

[2] In PY2023, some contractors were still using the previous year's T&C forms, which did not contain the ER questions. Other contractors did not return the form. The evaluation team expects the number of forms collected over time to increase as contractors are more familiar with new guidance that encourages the completion and submission of the forms.

# SCORING ALGORITHM

Table 2 shows how the T&C Form responses are used to classify units as ROF or ER. Each response is ultimately assigned a classification number, shown in the final column in Table 2.

Table 2. ER T&C Form Scoring Algorithm

| Tracking data | Terms & Conditions Form | | | | | Tracking data | Classification | Classification Number |
|---|---|---|---|---|---|---|---|---|
| *Function* | *Form Provided* | *ER1 - Operating Condition of Existing Unit* | *ER2 - Repair Option offered by contractor?* | *ER3 - Why did you choose not to repair?* | | *Age of replaced unit* | | |
| | Not Provided -- or -- Old Form | | | | | | Drop | |
| | All blank or Unsure | | | | | | Drop | 99 |
| NC or Addition | | | | | | | TOS | 0 |
| Operating Compressor -- or -- Failed Compressor | New Form | 1. Unit(s) ran when turned on and provided sufficient cooling for my space | | | | | ER | 1 |
| | | 2. Unit(s) ran when turned on but did not provide sufficient cooling for my space (it worked but not well) | 1. Yes | 1. Repair cost was too high to make feasible, so I/we did not consider repairing the unit(s) | | | ROF | 2 |
| | | | | 2. Repairs were a feasible option but I/we decided to replace the [UNIT] instead | | | ER | 3 |
| | | 98. Unsure | 98. Unsure | 0. Other, please specify | Clear open end | | ER or ROF | 4 |
| | | 99. Blank | 99. Blank | 98. Unsure | Unclear/blank | <=PY23 mean age | ER | 5 |
| | | | | 99. Blank | open end | >PY23 mean age | ROF | 6 |
| | | | 2. No | | | | ROF | 7 |
| | | 3. Unit(s) did not run when turned on / it was not working | 1. Yes | 1. Repair cost was too high to make feasible, so I/we did not consider repairing the unit(s) | | | ROF | 8 |
| | | | 99. Blank | 2. Repairs were a feasible option but I/we decided to replace the [UNIT] instead | | | ER | 9 |
| | | | | 0. Other, please specify | Clear open end | | ER or ROF | 10 |
| | | | | | Unclear open end | <=PY23 mean age | ER | 11 |
| | | | | | | >PY23 mean age | ROF | 12 |
| | | | | 98. Unsure 99. Blank | | | ROF | 13 |
| | | | 2. No 98. Unsure | | | | ROF | 14 |

In cases where the algorithm considers an open-ended response to ER3 in the determination, the evaluation team categorized the open-ended response according to the rules outlined in Table 3. When the open-ended responses are unclear or blank, the algorithm relies on age to determine ER/ROF. According to an agreement with the Independent Auditor, reached as part of the PY2022 evaluation, we compared the age of the respondent's unit with the mean age of all units in the program-tracking data, which was 21.3 years. If the age of the respondent's unit was less than or equal to the mean age, we considered the unit to be ER; if the age of the respondent's unit was greater than the mean age, we considered the unit to be ROF.

Table 3. Open End Assignment Rules

| Rule Number | Open End | Classification |
|---|---|---|
| 1 | The response clearly indicates a failed unit (e.g., the unit was not repairable, the unit would have failed anyway, the unit was too old to repair, or repairs did not work) | ROF |
| 2 | The cost of repairs was too high to justify | ROF |
| 3 | Equipment necessary to fix the unit was difficult to find/ no longer sold (i.e., Leaking Freon, Freon is no longer imported as of January 2020[3]) | ROF |
| 4 | Repairs were "stop-gap"/ temporary solution | ROF |

[3] U.S. Environmental Protection Agency, "Homeowners and Consumers: Frequently Asked Questions," accessed February 26, 2024, https://www.epa.gov/ods-phaseout/homeowners-and-consumers-frequently-asked-questions.

| Rule Number | Open End | Classification |
|---|---|---|
| 5 | The response indicates that the unit was perhaps still functional, just old, and the respondent wanted it replaced | ER |
| 6 | Response mentions the unit was part of an addition or NC | NC |
| 7 | Response only mentions age | Use Age |
| 8 | Response unclear or not related to ER/ROF classification (e.g., resizing to fit house properly) | Use Age |
| 9 | No open end provided | Use Age |

## EARLY REPLACEMENT RESPONSE FREQUENCIES

The frequencies of each classification number are provided in Table 4 below. Of the 3,630 valid responses, the most common response classification numbers were 3 (22%), 1 (21%), and 2 (18%). Only 6% of responses were classified based on open-ended responses (classification numbers 4 and 10) and 4% based on age (classification numbers 5, 6, 11, and 12).

Table 4. T&C ER Classification Number Frequencies

| Classification Number | Classification | Frequency | Percent of Responses |
|---|---|---|---|
| 0 | TOS | 241 | 7% |
| 1 | ER | 773 | 21% |
| 2 | ROF | 645 | 18% |
| 3 | ER | 785 | 22% |
| 4 | ER or ROF | 155 | 4% |
| 5 | ER | 75 | 2% |
| 6 | ROF | 69 | 2% |
| 7 | ROF | 205 | 6% |
| 8 | ROF | 307 | 8% |
| 9 | ER | 116 | 3% |
| 10 | ER or ROF | 64 | 2% |
| 11 | ER | - | 0% |
| 12 | ROF | - | 0% |
| 13 | ROF | 65 | 2% |
| 14 | ROF | 130 | 4% |
| **Total Valid Responses** | | **3,630** | **100%** |

# APPENDIX C. PAY AS YOU SAVE (PAYS)

## ENGINEERING ANALYSIS FOR TIER I MEASURES

Table 5 summarizes per-unit ex ante and ex post energy and demand savings for Tier 1 measures along with associated gross realization rates. Realization rates for these measures ranged from 36% for low-flow bathroom faucet aerators to 78.2% for advanced power strips. For low-flow showerheads, aerators, and water heater pipe wrap, ex post savings rely on TRM-recommended electric domestic water heating fuel type assumptions applied based on available information from program-tracking data. The evaluation team applied the EISA-stipulated 45 lumens/watt baseline efficiency for standard LED lighting measures to all lamps with install dates on or after August 1, 2023. This affected 42% of all Tier 1 incented lamps. For all measure categories, ex post savings reflect survey-based ISRs developed during the PY2022 evaluation. For measure categories that do not rely on water heater fuel type assumptions, differences between ex ante and ex post savings are primarily attributable to the application of PY2022-developed ISR assumptions.

Table 5. PAYS Tier 1 Per-Unit Savings

| Measure Category | Energy Savings | | | Demand Savings | | |
|---|---|---|---|---|---|---|
| | Ex Ante (kWh) | RR | Ex Post (kWh) | Ex Ante (kW) | RR | Ex Post (kW) |
| Standard LED Lighting | 32.51 | 68.8% | 22.36 | 0.0050 | 69.4% | 0.0035 |
| Advanced Power Strips | 29.45 | 78.2% | 23.03 | 0.0034 | 78.2% | 0.0026 |
| Low-Flow Showerheads | 87.16 | 65.1% | 56.77 | 0.0077 | 42.4% | 0.0033 |
| Faucet Aerators – Bath | 35.17 | 36.0% | 12.65 | 0.0031 | 36.0% | 0.0011 |
| Faucet Aerators – Kitchen | 111.03 | 36.2% | 40.18 | 0.0099 | 36.2% | 0.0036 |
| Water Heater Pipe Wrap | 4.64 | 44.0% | 2.04 | 0.0004 | 44.0% | 0.0002 |

## ENERGY MODEL ANALYSIS FOR TIER 4 RETROFIT MEASURES

Our Tier 4 energy model analysis consisted of a desk review of project documentation and a thorough review of modeling files for 20 sampled projects representing 11% of total Tier 4 projects and 10% of total ex ante energy savings associated with Tier 4 measures. For all 20 sampled projects, we were able to replicate ex ante savings for Tier 4 measures using the OptiMiser modeling software employed by the implementation team. We then updated model specifications to align with available project details and developed realization rates for each project. The overall realization rate for the projects was 92.6%.

Table 6 summarizes the key drivers of differences between ex ante and ex post savings for each of the sampled projects.

Table 6. PAYS Tier 4 Energy Model Review Findings (Exclusive of ISR)

| Project ID | Ex Ante kWh Savings | Ex Post kWh Savings | RR | Key Drivers of Differences |
|---|---|---|---|---|
| ODC001 | 265 | 258 | 97% | ▪ Updated the initial CFM<br>▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated the weather station<br>▪ Updated the billing data |
| ODC002 | 8,010 | 8,096 | 101% | ▪ Updated conditioned and attic floor area<br>▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated the weather station |

| Project ID | Ex Ante kWh Savings | Ex Post kWh Savings | RR | Key Drivers of Differences |
|---|---|---|---|---|
| ODC003 | 3,070 | 2,473 | 81% | ▪ Updated conditioned and attic floor area<br>▪ Updated the deemed savings for Smart Power Strip and LEDs<br>▪ Updated the weather station |
| ODC004 | 273 | 279 | 102% | ▪ Updated Weather Station<br>▪ Updated utility data |
| ODC005 | 9,488 | 9,678 | 102% | ▪ Updated Weather Station<br>▪ Updated utility data |
| ODC006 | 1,205 | 687 | 57% | ▪ Updated Insulation square footage<br>▪ Savings claimed for (2) thermostats, double counting the savings from (1) thermostat<br>▪ Removed Air Sealing measure due to no verified cfm reduction<br>▪ Updated utility data |
| ODC007 | 7,764 | 7,636 | 98% | ▪ Zero lighting savings – Assuming Tier 1 is handled separately |
| ODC008 | 1,897 | 1,204 | 63% | ▪ Updated duct leakage reduction rate from 77% to 59% based on documentation<br>▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated the weather station |
| ODC009 | 2,024 | 1,911 | 94% | ▪ Updated the final CFM (infiltration reduction)<br>▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated the building sq. ft. |
| ODC010 | 2,295 | 2,374 | 103% | ▪ Updated utility data<br>▪ Updated the deemed savings for Smart Power Strip, aerator, and showerhead<br>▪ Updated the building sq. ft.<br>▪ Included attic insulation<br>▪ Updated heating output capacity to 96000; ex ante used input capacity 100000 in the model, but the model requires output. |
| ODC011 | 2,509 | 2,998 | 119% | ▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated the weather station |
| ODC012 | 8,595 | 8,643 | 101% | ▪ Updated the deemed savings for Smart Power Strip and LEDs<br>▪ Updated billing data<br>▪ Updated conditioned sq. ft.<br>▪ Updated the weather station |
| ODC013 | 2,311 | 2,682 | 116% | ▪ Updated the deemed savings for Smart Power Strip and LEDs<br>▪ Updated billing data<br>▪ Updated the weather station |
| ODC014 | 2,164 | 2,027 | 94% | ▪ Updated the initial CFM (infiltration reduction)<br>▪ Updated the deemed savings for Smart Power Strip<br>▪ Updated weather station<br>▪ Updated utility data |
| ODC015 | 2,765 | 1,714 | 62% | ▪ Savings claimed for (2) thermostats, double counting the savings from (1) thermostat<br>▪ LED lamps claimed in Tier 1 that also appeared in the Tier 4 model were removed from deemed savings<br>▪ Updated conditioned sq. ft.<br>▪ Updated the deemed savings for Smart Power Strip and LEDs<br>▪ Updated weather station |
| ODC016 | 5,997 | 5,687 | 95% | ▪ Updated the deemed savings for Smart Power Strip, kitchen and bath aerator, and LEDs<br>▪ Updated weather station |
| ODC017 | 3,370 | 1,819 | 54% | ▪ Updated billing data<br>▪ Updated the deemed savings for Smart Power Strip, bath aerator, showerheads, and LEDs for EISA compliance<br>▪ Updated weather station |

| Project ID | Ex Ante kWh Savings | Ex Post kWh Savings | RR | Key Drivers of Differences |
|---|---|---|---|---|
| ODC018 | 697 | 209 | 30% | ▪ Updated the deemed savings for Smart Power Strip and LEDs for EISA compliance<br>▪ Updated weather station |
| ODC019 | 715 | 178 | 25% | ▪ Updated the deemed savings for Smart Power Strip, showerheads, bath aerator, and LEDs for EISA compliance<br>▪ Updated weather station |
| ODC020 | 834 | 786 | 94% | ▪ Updated the deemed savings for showerheads, bath aerators, and LEDs |
| **Overall** | **66,248** | **61,340** | **92.6%** | |

Inconsistencies between energy model specifications and available documentation for a small number of projects included in our energy model analysis accounted for a large portion of the differences between ex ante and ex post savings.

For three projects (ODC017–ODC019), realization rates are low due to the outsized contribution of lighting measures to overall project savings (ranging from 56% to 80%) and the application of EISA-stipulated 45 lumens/watt baselines as these projects have completion dates on or after August 1, 2023. The majority of ex ante savings for these projects come from specialty lighting measures with baseline wattage efficiency far above the EISA-stipulated 45 lumens/watt. Adjusting baselines for those measures drastically reduced ex post savings relative to ex ante.

For two projects (ODC006 and ODC008), infiltration reductions were revised based on photo evidence, resulting in lower realization rates. For ODC008, photos showed an overall reduction from duct sealing of 186 CFM50, in contrast to the 430 CFM50 reduction entered into the energy model. Duct Sealing was 69% of the project's savings, and this finding was a driver of the low realization rate of this project.

In project ODC006, photos did not support the claim of a reduction in envelope infiltration from air sealing, and the savings were zeroed out in ex post. Air sealing savings were only 6% of the total project savings and were not a driver of the low realization rate for this project. The driving factor was an update to the attic floor area, which reduced savings from the attic insulation measure. The energy model used an attic floor area of 1,692 sqft, but project photos showed an attic floor area of 1,092 sqft. Attic insulation accounted for 71% of project savings, and the reduction in floor area resulted in a realization rate of 64% for the measure.

For two projects (ODC006 and ODC015), the evaluation team found discrepancies within the smart thermostat measure. In both instances, two smart thermostats were incented and installed in the homes. The savings claimed in the project-tracking data equaled double the savings reported in the energy model. There are restrictions in the Ameren Missouri TRM limiting savings to one smart thermostat per household; however, the savings can account for the total heating and cooling capacity as long as a smart thermostat controls that capacity. The energy model accounts for both thermostats, and savings did not need to be doubled in the project data. The evaluation team utilized the revised energy models' output savings for the smart thermostat measure, reducing savings for both projects.

We updated weather assumptions for 14 of the 20 projects to use industry-standard weather stations.[4] We also updated LED lighting savings assumptions for 10 of the 20 projects. In these cases, the energy model included generalized assumptions regarding LED baselines and installed wattages and often included Tier 1 standard LEDs, which were removed to avoid double counting these savings from the Tier 1 analysis. Ex post savings for Tier 4 specialty

[4] Weather stations associated with Typical Meteorological Year version 3 (TMY3) datasets (e.g., St. Louis International Airport for projects in the St. Louis area).

lighting instead used Missouri TRM Version 6.0 Appendix F deemed per-unit savings assumptions, which we applied to quantities included in supplemental program-tracking data.

# APPLICATION OF EVALUATION RESULTS

This section summarizes gross impact results for the PY2023 PAYS Program by measure category. For Tier 1 measures, RRs reflect the difference between ex ante and ex post per-unit savings that rely on appropriate TRM-recommended per-unit savings and survey-based ISRs developed as part of the PY2022 evaluation for each Tier 1 measure category. For Tier 4 measures, the realization rate reflects a savings-weighted average of results from our modeling review of 20 sampled projects developed as part of the current evaluation for each Tier 4 measure category. Table 7 presents ex ante savings by channel and measure category, the realization rates for Tier 1 and Tier 4 measures, and survey-based ISRs used to calculate ex post savings.

Table 7. Ex Ante Savings by Channel

| Channel | Measure Category | Energy Savings | | | Demand Savings | | |
|---|---|---|---|---|---|---|---|
| | | Ex Ante (MWh | RR | Ex Post (MWh) | Ex Ante (MW) | RR | Ex Post (MW) |
| Tier 1 Direct Install | Standard LED Lighting | 98 | 68.8% | 67 | 0.015 | 69.4% | 0.011 |
| | Advanced Power Strip | 47 | 78.2% | 37 | 0.005 | 78.2% | 0.004 |
| | Low-Flow Showerhead | 32 | 65.1% | 21 | 0.003 | 42.4% | 0.001 |
| | Bathroom Faucet Aerator | 17 | 36.0% | 6 | 0.002 | 36.0% | 0.001 |
| | Water Heater Pipe Wrap | 15 | 44.0% | 6 | 0.001 | 44.0% | 0.001 |
| | Kitchen Faucet Aerator | 13 | 36.2% | 5 | 0.001 | 36.2% | 0.000 |
| | *Tier 1 Subtotal* | *222* | *64.1%* | *142* | *0.027* | *63.9%* | *0.017* |
| Tier 4 Retrofit | HVAC | 441 | 92.6% | 408 | 0.205 | 92.6% | 0.190 |
| | Attic Insulation | 80 | 90.6% | 72 | 0.037 | 90.6% | 0.034 |
| | Smart Thermostat | 59 | 88.4% | 52 | 0.028 | 88.4% | 0.024 |
| | Air Sealing | 30 | 90.6% | 27 | 0.014 | 90.6% | 0.013 |
| | Specialty LED Lighting | 22 | 83.5% | 18 | 0.003 | 83.5% | 0.003 |
| | Duct Sealing | 12 | 90.6% | 11 | 0.006 | 90.6% | 0.005 |
| | Tier 1 Measures [A] | 1 | N/A | N/A | 0.000 | N/A | N/A |
| | *Tier 4 Subtotal* | *644* | *91.4%* | *588* | *0.293* | *91.7%* | *0.269* |
| **Total** | | **865** | **84.4%** | **731** | **0.320** | **89.3%** | **0.286** |

[A] Tier 1 measures included in Tier 4 tracking data were excluded to avoid double counting of associated savings.

*Note:* Individual values may not sum to totals due to rounding.

# APPENDIX D. ARREARAGE ANALYSIS

## INCOME ELIGIBLE PARTICIPANT BILL PAYMENT ANALYSIS

### DATA CLEANING AND PREPARATION

#### Participant Data

The evaluation team compiled a participant dataset by combining historical records of participants in the Single Family Income Eligible (SFIE) and Multifamily Income Eligible (MFIE) Programs between January 1, 2019, and December 31, 2022. The dataset contained a variety of fields, including service address, account active and inactive dates, measures received, measure installation dates, and program year evaluated. We carefully reviewed the measure installation dates for each participant, which was important to categorize billing periods into pre- and post-installation periods accurately. Additionally, this step ensured that we excluded billing periods from the analysis where program measures had already been installed. We found that some participants had a very long period of time between their minimum and maximum measure installation dates. Ultimately, the evaluation team excluded 297 participants with a project length greater than one year from our analysis. In addition, we excluded 225 participants for whom we did not receive any billing data for the twelve months before or after their participation.

#### Billing Data

We obtained monthly billing data from Ameren Missouri, including usage (kWh) and bill amounts ($). Data were requested for all PY2019 through PY2022 SFIE and MFIE participants from January 1, 2018, through September 30, 2023, to include one year of pre- and one year of post-installation data for all participants. Upon merging the participant and billing data, we performed the following data cleaning steps:

- **Inadequate days:** We identified and dropped bill periods with zero or very few days.
- **Duplicate and overlapping records:** We explored duplicate records and overlapping bills and made adjustments to arrive at a single bill per period.
- **Extremely low Average Daily Consumption (ADC):** We checked for and dropped bills with very low (less than 0 kWh) or missing average usage.
- **Extremely high ADC:** We removed customers with entire pre- or post-installation periods with very high average usage (exceeding 400 daily kWh).
- **Inadequate billing history before or after program participation**: Many energy-saving measures in these programs are expected to generate energy savings throughout the year. To assess changes in consumption and bills due to program measures before and after installation, we needed to ensure that participants had a billing history covering at least nine months (or the 270-day equivalent) in the pre- and post-installation periods.
- **Insufficient billing history in the cooling season before and after program participation**: We required participants to have a billing history covering a minimum of 75% of the cooling season (June through August) in the pre- and post-participation periods.
- **Insufficient billing history in the heating season before and after program participation**: Similar to the cooling season, we required participants to have a billing history covering a minimum of 75% of the heating season (December through February) in the pre- and post-participation periods.

Table 8 summarizes the accounts dropped due to each cleaning step. The largest drops were associated with insufficient pre-period and post-period billing data. After the data cleaning, we retained 39% of participants with billing data.

Table 8. Summary of Billing Data Cleaning Results

| Drop Reason | Accounts Remaining | |
|---|---|---|
| | N | % |
| Initial Count | 5,869 | 100% |
| Inadequate days | 5,750 | 98% |
| Duplicate and overlapping records | 5,750 | 98% |
| Extremely low ADC | 5,740 | 98% |
| Extremely high ADC | 5,733 | 98% |
| Inadequate billing history before or after program participation | 3,245 | 55% |
| Insufficient billing history in the cooling season before and after program participation | 2,817 | 48% |
| Insufficient billing history in the heating season before and after program participation | 2,292 | 39% |
| **Final Count** | **2,292** | **39%** |

### Disconnection Data

Ameren Missouri provided records of initial disconnection notices sent to SFIE and MFIE Program participants from PY2019 through PY2022 due to nonpayment between January 1, 2018, and September 30, 2023. The dataset contained account identifiers, the notice date, the reason the notice was sent, and the account balance at the time of the notice. The evaluation team merged the disconnection notice dataset into the final clean billing dataset so that for every billing period in the pre- and post-installation period, we were able to identify whether the customer received or did not receive a disconnection notice. If the customer received a disconnection notice, we noted the amount due at the time of the disconnection notice. If a customer received multiple disconnection notices in the same month, we calculated an average of the amount due for each disconnection notice received. We excluded March 2020 through June 2020 from the final disconnection dataset used for modeling due to a moratorium on disconnections in response to the COVID-19 pandemic, as reported by Ameren Missouri and observed in the data.

### Weather Data

To include weather patterns in our models, we used daily weather data from numerous weather stations across Ameren Missouri's territory. We utilized the site closest to each account's geographic location. Using multiple sites increased the accuracy of the weather data associated with each account. We obtained these data from the National Climatic Data Center (NCDC).

The monthly data are based on hourly average temperature readings from each day. We calculated cooling degree-days (CDD) and heating degree-days (HDD) for each day (in the analysis based on average daily temperatures, using the same formula used in weather forecasting). We then merged daily weather data into the consumption dataset so that each billing period captured the HDD and CDD for each day within that billing period. For analysis purposes, we calculated average daily HDD and average daily CDD for each billing period.

## COMPARISON GROUP EXPLORATIONS

For this analysis, we originally intended to withhold more recent participants within the evaluation period (July 2021–December 2022) to use as a comparison group. The appropriate use of a quasi-experimental comparison group design depends on the comparison group's equivalency with the treatment group (in this case, participants from January 2019–June 2021) on as many dimensions as possible during the pre-participation period. Substantial differences

between the treatment and comparison groups lead to a misrepresentation of the baseline or point of comparison. Therefore, as part of our assessment of the comparison group equivalency, we explored the following dimensions:

- Pre-period consumption
- Pre-period disconnection patterns
- Weather

Figure 1 compares energy consumption patterns between the treatment and comparison groups. As can be seen in the figure, consumption patterns are substantially different in the period from October 2019 through April 2020.

Figure 1. Participant and Comparison Group Usage During Pre-Installation Period

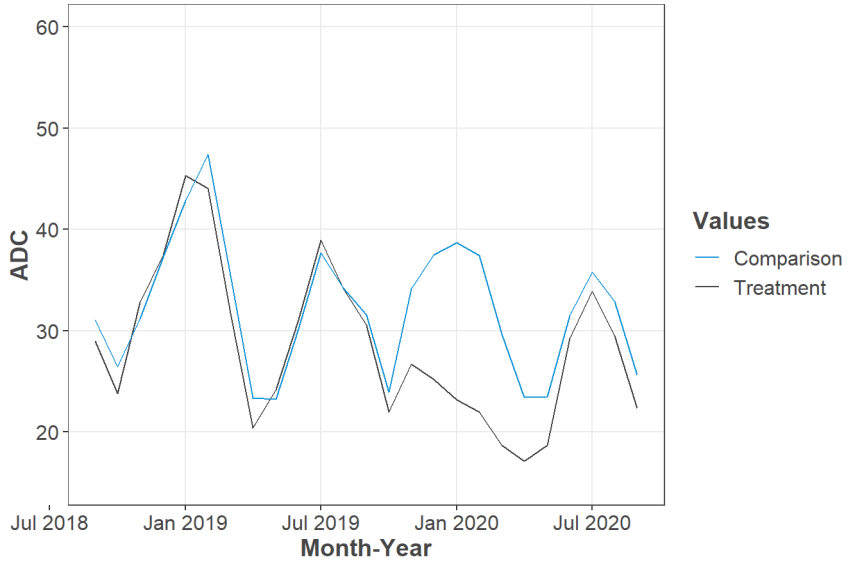



Figure 2 compares the percentage of treatment and comparison group participants receiving a disconnection notice each month. Historically, comparison group participants received disconnection notices at a higher rate than the treatment group. However, the treatment group received disconnection notices at a higher rate in 2020, following the COVID-19 moratorium on disconnections.

Figure 2. Participant and Comparison Group Disconnection Patterns During Pre-Installation Period

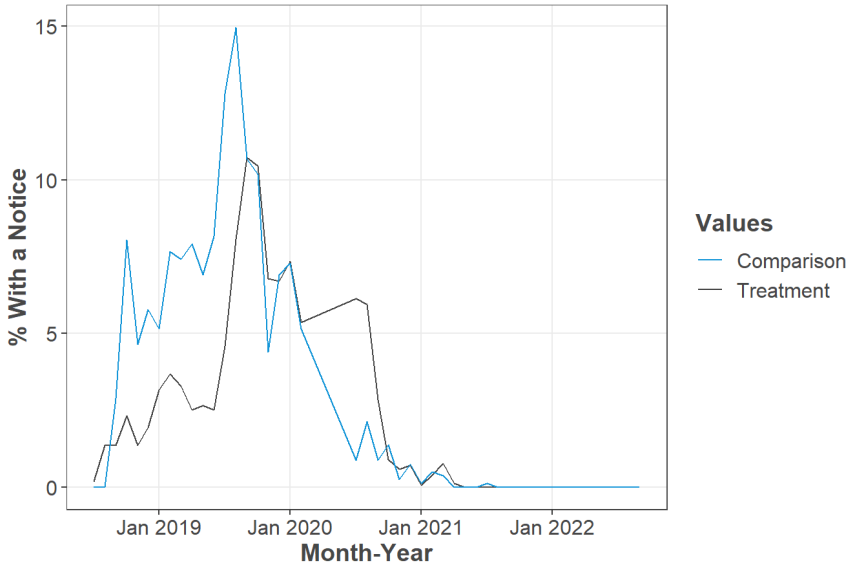



Figure 3 and Figure 4 show a comparison of CDD and HDD patterns between the treatment and comparison groups over time. The weather experienced by the treatment and comparison groups was similar.

Figure 3. Participant and Comparison Group Cooling Degree Days During Pre-Installation Period

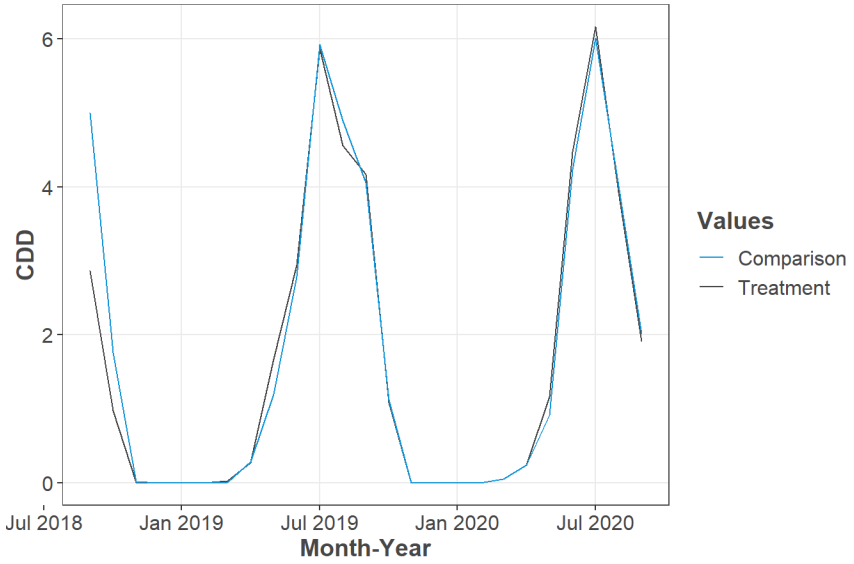
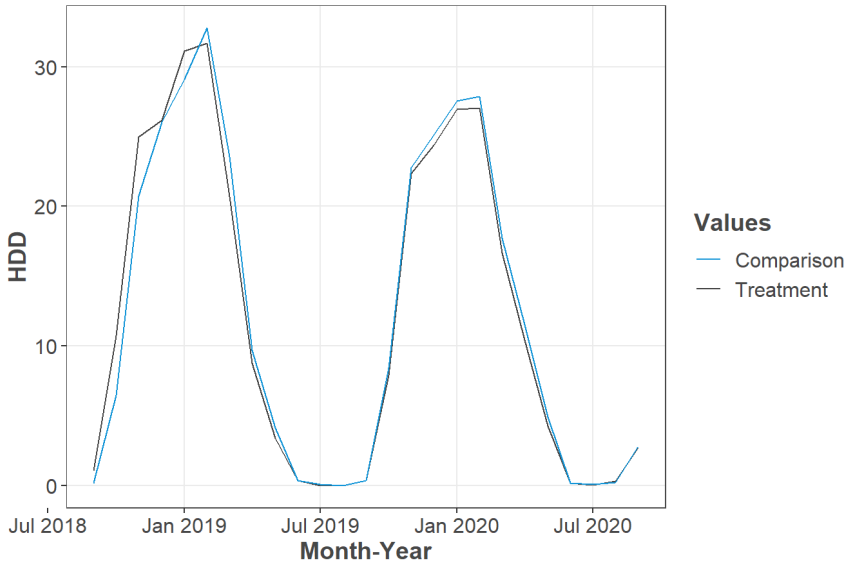


Figure 4. Participant and Comparison Group Heating Degree Days During Pre-Installation Period




Based on the findings of the equivalency analysis, the evaluation team determined that the comparison group could not be used to create an accurate baseline. Consequently, we proceeded with a pre-post analysis of all participants between PY2019 and PY2022 with sufficient data to be included in the modeling.

# MODELING

We specified models for three dependent variables as part of this effort. In all cases, we judged our final models on several criteria. Primarily, we aimed to use a model that explained as much about changes in the dependent variable as possible. The most direct measure of this is the adjusted R-squared, which estimates how much the model explains the differences between post-period patterns (e.g., in consumption or disconnection notices received) and the baseline. We also compared the Akaike Information Criterion (AIC) values of each model specification within the same sample. The AIC provides a measure of relative quality between models; a lower value indicates a relatively more efficient model. This method inherently incorporates explained variation and how many variables we use to achieve that level of explanation.

## Consumption Analysis

Using monthly consumption data, we specified a linear fixed effect regression (LFER) model in a pre-post design that incorporates weather and interaction terms to show the effect of weather in the post-installation period. The fixed effect for the model is set at the account level, which allows us to control for all household factors that do not vary over time. In determining the appropriate model for the analysis, we specified a range of models, from simple pre-post to more complex models incorporating various terms and controls.

Equation 1 represents the final model specification.

Equation 1. Final Model Specification - Energy Savings

$$ADC_{it} = \alpha_i + B_{1-11}MonthDummies_t + B_{12}Post_{it} + B_{13}CDD_{it} + B_{14}HDD_{it} + B_{15}Post_{it}CDD_{it} + B_{16}Post_{it}HDD_{it} + B_{17}COVID_{it} + B_{18}Post_{it}COVID_{it} + B_{19}Post_{it}SingleFamily_i + \varepsilon_{it}$$

Where:

$ADC_{it}$ = Average daily consumption (in kWh) for a participant *i* in billing month *t*

$MonthDummies_t$ = Indicator for a given calendar month

$Post_{it}$ = Indicator for the post-installation period (coded "0" in the pre-participation period, coded "1" in the post-installation period)

$HDD_{it}$ = Average daily heating degree days from NCDC

$CDD_{it}$ = Average daily cooling degree days from NCDC

$Post_{it}CDD_{it}$ = Average daily cooling degree days from NCDC interacted with the post-installation period

$Post_{it}HDD_{it}$ = Average daily heating degree days from NCDC interacted with the post-installation period

$COVID_{it}$ = Indicator for the COVID-19 period of March through June 2020 (coded "0" in the non-COVID-19 period and "1" in the COVID-19 period)

$Post_{it}COVID_{it}$ = COVID-19 period indicator interacted with the post-installation period

$Post_{it}SingleFamily_{it}$ = Indicator for single family homes (coded "0" for multifamily homes and "1" for single family homes) interacted with the post-installation period

$\alpha_i$ = Household-specific constant

$B_{1-11}$ = Increments in ADC associated with each calendar month, using January as a reference month

$B_{12}$ = Main program effect (change in ADC associated with being a participant in the post-installation program period)

$B_{13}$ = Increment in ADC associated with one-unit increase in CDD

$B_{14}$ = Increment in ADC associated with one-unit increase in HDD

$B_{15}$ = Increment in ADC associated with one-unit increase in CDD in the post-installation period

$B_{16}$ =Increment in ADC associated with one-unit increase in HDD in the post-installation period

$B_{17}$ = Increments in ADC associated with being in the COVID-19 period

$B_{18}$ = Increments in ADC associated with being in the COVID-19 period, specifically in the post-installation program period

$B_{19}$ = Increments in ADC associated with being a single family home, specifically in the post-installation program period

$\varepsilon_{it}$ = Error term

### Likelihood of Receiving Disconnection Notice

Using the disconnection notice dataset described above, we specified a logistic regression model to estimate the change in odds of receiving a disconnection notice in the post-installation period. The model incorporates weather and accounts for seasonal differences in the likelihood of receiving a notice. In determining the appropriate model for the analysis, we specified a range of models with various terms and controls.

Equation 2 represents the final model specification.

Equation 2. Final Model Specification - Disconnection Notice Likelihood

$$NoticeReceived_{it} = \alpha_i + B_{1-11}MonthDummies_t + B_{12}Post_{it} + B_{13}CDD_{it} + \varepsilon_{it}$$

Where:

$NoticeReceived_{it}$ = Indicator for participant *i* in month *t* who received a disconnect notice (coded "0" for no disconnect notice received and "1" for disconnect notice received)

$MonthDummies_t$ = Indicator for a given calendar month

$Post_{it}$ = Indicator for the post-installation period (coded "0" in the pre-participation period, coded "1" in the post-installation period)

$CDD_{it}$ = Average daily cooling degree days from NCDC

$\alpha_i$ = Household-specific constant

$B_{1-11}$ = The log-odds ratio of receiving a disconnect notice associated with each calendar month with respect to the reference month (January)

$B_{12}$= The log-odds ratio of receiving a disconnect notice in the post-period with respect to the pre-period

$B_{13}$= The change in the log-odds of receiving a disconnect notice associated with a one-unit increase in CDD

$\varepsilon_{it}$ = Error term

### Amount Due at Time of Disconnection Notice

We specified a LFER model in a pre-post design using the disconnection notice dataset described above. The fixed effect for the model is set at the account level, which allows us to control for all household factors that do not vary over time. In the process of determining the appropriate model for the analysis, we specified a range of models, from simple pre-post to more complex models incorporating a variety of terms and controls. We determined that a simple pre-post model is most appropriate in this case.

Equation 3 represents the final model specification.

Equation 3. Final Model Specification - Disconnection Balance Amount

$$NoticeBalance_{it} = \alpha_i + B_1Post_{it} + \varepsilon_{it}$$

Where:

$NoticeBalance_{it}$ = The notice balance for participant *i* in month *t* when they received a disconnect notice

$Post_{it}$ = Indicator for the post-installation period (coded "0" in the pre-participation period, coded "1" in the post-installation period)

$\alpha_i$ = Household-specific constant

$B_1$ = Main program effect (change in disconnect notice balance associated with being a participant who received a disconnect notice in the post-installation program period)

$\varepsilon_{it}$ = Error term

## CONVERSION OF ENERGY USAGE TO BILLS

We applied the average per-kWh energy charge based on the current Residential Anytime Service rate to convert energy savings as estimated through the consumption analysis to bill savings.[5] The resulting bill amounts reflect the portion of the bill that fluctuates based on the amount of energy used and excludes flat fees and riders that would not vary due to changes in energy consumption.

The Residential Anytime Service rate includes varying per-kWh charges depending on the time of year and, in the winter, the amount of energy the customer uses in the billing period. We generated a weighted per-kWh charge based on the time represented by the summer and winter pricing seasons. Further, we reviewed participant bills to determine the proportion of their winter energy use falling within each winter pricing tier. We arrived at a weighted rate of $0.10 per kWh, which was applied to the energy savings to arrive at bill savings (Table 9).

Table 9. Per kWh Rate Assumptions

| Charge Category | Price / kWh ($) | Weight |
|---|---|---|
| Summer (June – September) | $0.1372 | 33% |
| Winter (October – May) | | |
| Tier 1 < 750 kWh | $0.0934 | 44% |
| Tier 2 > 750 kWh | $0.0627 | 23% |
| **Average Charge** | **$0.1010** | |

[5] Effective December 3, 2023: https://www.ameren.com/-/media/rates/files/missouri/uecsheet54rate1mres.ashx

Opinion **Dynamics**

## CONTACT:

Antje Flanders
Vice President

aflanders@opiniondynamics.com

BOSTON
PORTLAND
SAN DIEGO
SAN FRANCISCO