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Ameren Missouri Program Year 2019 Annual EM&V Report

Volume 2: Residential Portfolio Appendices

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Appendix A. Detailed Impact Analysis Methodology

Residential Lighting

Gross Impact Methodology

Electricity Savings

To calculate verified gross energy and demand savings for PY2019 Residential Lighting Program, used savings assumptions from the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database for most items. Through evaluation research, we estimated and applied leakage of bulbs to non-Ameren Missouri customers, in-service rates, and the percentage of bulbs installed in residential versus commercial locations. In the sections below, we provide additional details on the methods used to estimate these items.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 1.

Equation 1. Energy and Demand Savings Equation

$$\Delta\, kWh = LA \times\ RES \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res} \times HOU_{res} \times WHFe_{res}\right]$$

$$+ LA \times COM \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com} \times HOU_{com} \times WHFe_{com}\right]$$

$$\Delta\, kW = \Delta\, kWh * kW\ Factor$$

Where:

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
RES = Residential proportion of installed bulbs
COM = Commercial proportion of installed bulbs
Base Watt = EISA-compliant base wattage
Bulb Watt = Actual wattage of installed bulb
ISR = In-service rate
HOU = Hours of use
WHFe = Waste heat factor for energy savings
WHFd = Waste heat factor for energy savings
kW Factor = kW conversion factor
Res = Residential values
Com = Commercial values

Table 1 presents the sources of savings assumptions used to calculate program ex post gross energy and demand savings.

Table 1. Ex Post Savings Assumption Sources

Assumption	Online Store		Upstream Lighting	
	Source of Residential Assumption	Source of Commercial Assumption	Source of Residential Assumption	Source of Commercial Assumption
Sales to residential/ commercial customers	2019 Participant Survey		2019 Intercept Study	
Leakage rate				
Baseline wattage	Minimum efficiency baseline adjusted for EISA and DOE Energy Conservation Standards			
Replacement wattage	Actual product wattage			
HOU	November 2019 Ameren Missouri TRM			
First-year ISR and future installation rate trajectory	2019 Participant Survey		2019 Intercept Study	
Interactive effects	2019 Ameren Missouri TRM			
kW factor				

Table 2 provides the savings assumptions used to calculate ex post gross savings. Following the table, we provide greater detail on each assumption.

Table 2. Ex Post Savings Assumption Values

Assumption	Online Store		Upstream Lighting	
	Residential Assumption	Commercial Assumption	Residential Assumption	Commercial Assumption
Sales to residential/ commercial customers	100%	0%	96%	4%
Leakage rate	0%		4%	
Baseline wattage	Minimum efficiency baseline adjusted for applicable federal standards in place during the evaluation period			
Replacement wattage	Actual product wattage			
HOU	995	3,612	995	3,612
ISR	80% (Standard) 80% (Reflector) 84% (Specialty)		88% (Standard) 90% (Reflector) 93% (Specialty)	
Interactive effects	0.99	1.1	0.99	1.1
kW factor	0.0001492529	0.0001899635	0.0001492529	0.0001899635

Base Watts

The evaluation team used the minimum efficiency baseline approach to determine baseline wattages for program-discounted bulbs for both programs (in both residential and commercial settings). Minimum efficiency standards in the market vary by product type based on federal standards. As the first step, we developed rated baseline wattages for each program-discounted product. We used the Energy Star qualified product list (QPL) to derive incandescent equivalent wattages. In cases, where the information was not available via the QPL, we researched and applied manufacturer-rated incandescent equivalent wattages from manufacturer product descriptions. We then adjusted those wattages based on the existing federal standards. Below we detail the adjustments we made.

Standard Products

We adjusted the wattages of the standard products based on the efficiency standards set forth in the first Phase of the Energy Independence and Security Act of 2007 (EISA 2007). The first Phase of EISA went into effect in January 2012 and affected standard screw-based light bulbs of most common wattages. Table 3 lists affected wattages and minimum efficiency wattages set forth by EISA 2007. For standard bulbs in these four wattage ranges, we used the minimum efficiency wattages listed in the table. For all other standard products, we used incandescent equivalent wattages as the baseline.

Table 3. EISA Baseline Wattages for Standard Screw Based Products

Incandescent Baseline Wattage	EISA Baseline Wattage
40	29
60	43
75	53
100	72

Reflector Products

As part of EISA 2007, DOE was required to set efficiency standards for wide range of reflector products, including PAR, BPAR, ER, and BR products. A subset of products was exempt from the standards, namely ER30, BR30, BR40, or ER40 lamps rated at 50 watts or less; BR30, BR40, or ER40 lamps rated at 65 watts, R20 lamps rated at 45 watts or less. For the exempt products, we used incandescent rated wattages. For all other products, we adjusted baseline wattages to account for EISA. Table 4 below provides baseline wattages by reflector and wattage.

Table 4. EISA Baseline Wattages for Standard Screw Based Products

Bulb Type	Lumen Range		Baseline Watts
	Lower End	Upper End	
Non-exempt R, PAR, ER, BR, BPAR, or similar bulb shapes with medium screw bases	400	599	45
	600	739	50
	740	849	50
	850	999	55
	1,000	1,300	65

Specialty Products

Neither EISA nor DOE Energy Conservation standards for incandescent reflector lamps affect other specialty products, such as three-way bulbs, candelabra bulbs, and globe bulbs. As such, we used incandescent equivalent wattage as the baseline for these specialty products.

Leakage

For both program delivery channels, the evaluation team estimated the percentage of program-discounted bulbs that were installed outside of Ameren Missouri territory. The Online Store only sells products to customers with a residential Ameren Missouri account.[1] Therefore, our participant survey asked respondents if they had installed the bulbs in their home or someplace else. If someplace else, we asked if this location received service from Ameren Missouri. We expected that leakage outside the territory from the Online Store to be small. In fact, we found that 0% of bulbs sold through the store were installed outside the territory and thus we applied a leakage rate of zero to all Online Store sales.

For the upstream channel where discounts are provided at the point-of-purchase, the program cannot verify that customers who purchase program-discounted bulbs are Ameren Missouri customers. We asked our in-store intercept respondents if they expected to install the bulbs in a location that received service from Ameren Missouri or from another utility. Survey results indicate that 4% of program-discounted bulbs would be installed outside the territory. We applied the 4% leakage rate to sales from the upstream channel.

Table 5. PY2019 Lighting Program Leakage Rates by Channel

Channel	Leakage
Upstream	4%
Online Store	0.0%

Residential/Commercial Split

Bulbs installed in commercial locations save more energy due to the higher hours of use. For the Online Store, our participant survey asked respondents if they had installed the bulbs in their home or someplace else. If someplace else, we asked where they installed and found that no respondents installed the bulbs in a business location. For the upstream channel, our in-store intercept respondents revealed that 4% of all bulbs being purchased were to be installed in business applications (Table 6).

Table 6. PY2019 Lighting Program Residential Install Rates by Channel

Channel	% Residential	% Business
Upstream	96%	4%
Online Store	100%	0.0%

In-Service Rates

We developed separate ISRs by bulb type and for LEDs purchased through the Online Store and upstream retailers based on participant surveys. For the Online Store, we asked survey respondents how many of the bulbs that they through the Online Store purchased were installed, and of those, if they had removed any. The final number serves as the Year 1 ISR. For in-store intercept customers, we had to ask them about their plans to install the LEDs they were purchasing that day. We asked customers how many of the LEDs they planned to install within the next six months to estimate Year 1 ISR.

Customers do not typically install all purchased bulbs within a year, but research studies across the country have found that customers will eventually most of them. Evaluators therefore need to account for those future savings in order to give the program proper credit for all the savings that it ultimately achieves. The

[1] When purchasing bulbs through the Online Store, there is a pop-up that appears asking shoppers to certify that they have residential electric service provided by Ameren Missouri and that they will install the bulb into a home served by their account.

two main approaches to claiming savings from these later installations are (1) staggering the savings over time and claiming some in later program years (staggered approach) and (2) claiming the savings from the expected installation in the program year in which the customers received the product but discounting the savings by a societal or utility discount rate (discounted approach).

As part of our evaluation, we used the discounted approach. To allocate installations over time, we used the installation trajectory recommended by the UMP.[2] The trajectory is based on a recent LED-specific Massachusetts study, which found that 24% of the LEDs that went into storage in year 1 were installed in year 2. Because the study is still ongoing, with only 2 years of data available at the time of the revised UMP publication, the UMP recommends that evaluators assume that customers continue to install LEDs in storage at a rate of 24% each year to estimate lifetime ISR. Table 7 outlines the approach to calculating incremental and cumulative installations over the five years following purchase.

Table 7. Installation Rate Trajectory

Year	Incremental ISR	Cumulative ISR
Year 1	Year 1 ISR	Year 1 ISR
Year 2	(1 – Year 1 ISR) * 24%	Year 1 ISR + Year 2 ISR
Year 3	(1 – Year 1 ISR – Year 2 ISR) * 24%	Year 1 ISR + Year 2 ISR + Year 3 ISR
Year 4	(1 – Year 1 ISR – Year 2 ISR – Year 3 ISR) * 24%	Year 1 ISR + Year 2 ISR + Year 3 ISR + Year 4 ISR
Year 5	(1 – Year 1 ISR – Year 2 ISR – Year 3 ISR – Year 4 ISR) * 24%	Year 1 ISR + Year 2 ISR + Year 3 ISR + Year 4 ISR + Year 5 ISR
Year 6	(1 – Year 1 ISR – Year 2 ISR – Year 3 ISR – Year 4 ISR – Year 5 ISR) * 24%	Year 1 ISR + Year 2 ISR + Year 3 ISR + Year 4 ISR + Year 5 ISR + Year 6 ISR

To claim savings from future installations of current sales, the evaluation team discounted all future savings by the utility-specified discount rate using the net present value (NPV) formula (Equation 2). We used a discount rate of 5.95%.

Equation 2. Net Present Value Formula

$$NPV = \frac{R_t}{(1+i)^t}$$

Where:

R = savings

t = number of years in the future savings take place

i = discount rate

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Where:

R = savings

t = number of years in the future savings take place

i = discount rate

[2] National Renewable Energy Laboratory (NREL). *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Chapter 6: Residential Lighting Protocol. October, 2017. https://www.nrel.gov/docs/fy17osti/68562.pdf.*

Table 8 shows the Year 1 ISRs and the Cumulative ISRs that we used to estimate program savings. The Year 1 ISRs vary by channel, with less than half (42%) of standard bulbs purchased online in-service compared to 66% for the upstream channel. Overall, customers purchasing LEDs through the Online Store look as if they tended to stock up, reducing their ISR – Online Store customers purchased, on average, 11.9 bulbs purchased per person compared to an average of 4.9 bulbs per person in-store.

Table 8. PY2019 Lighting Program In-Service Rates by Channel and Bulb Type

Channel	Year 1 ISR			Cumulative ISR		
	Standard	Reflector	Specialty	Standard	Reflector	Specialty
Online Store	42%	43%	54%	80%	80%	84%
Upstream	66%	71%	79%	88%	90%	93%

Net Impact Methodology and Results

A NTGR represents the portion of the gross energy savings associated with a program-supported measure or behavior change that would not have been realized in the absence of the program. In other words, the NTGR represents the share of program-induced savings. The NTGR consists of FR, SO, and NPSO and is calculated as $(1 - FR + SO + PSO)$. FR is the proportion of the program-achieved verified gross savings that would have been realized absent the program. There are two types of SO: participant and nonparticipant. Participant SO occurs when participants take additional energy-saving actions that are influenced by program interventions but that did not receive program support. NPSO is the reduction in energy consumption and/or demand by nonparticipants because of the influence of the program.

As part of this evaluation, the evaluation team estimated FR, PSO and NPSO. We used two overarching methods and three data sources (Table 9). For the Online Store, we used the participant self-report method to estimate FR and PSO using data from the participant survey. For the upstream channel, we used two methods to estimate FR: (1) participant self-reports using in-store intercept surveys, and (2) price elasticity modeling using program tracking data. We combined the results from the two methods to produce an estimate of FR for the upstream channel. We estimated upstream PSO and NPSO using self-reports from the intercepts survey.

Table 9. Sources of Net-to-Gross Components

Delivery Channel	Method	Data Source	FR	PSO	NPSO
Online Store	Self-Report	Online Store Participant Survey	✓	✓	
Upstream	Self-Report	In-Store Intercept Survey	✓	✓	✓
Upstream	Price Elasticity Modeling	Program Tracking Data	✓		

We developed an overall estimate of program FR by combining the results from the two delivery channels, weighted by channel ex post gross savings.

The final NTGR is based on this combined FR estimate, PSO from the two delivery channels, and NPSO from the upstream channel.

Free-Ridership

Free-riders are program participants who would have installed high-efficiency LED light bulbs on their own without the program. FR represents the percent of savings that would have been achieved in the absence of the program. In the next two sections, we provide details on the two methods we used to estimate free-ridership.

Participant Self-Report

The participant self-report method relies on survey interviews with program participants that asks them to assess: (1) the influence of the program and its different components on the decision to purchase an energy efficient measure, and (2) what they would have purchased if the program did not exist.

Accordingly, our FR assessment consisted of the following two components:

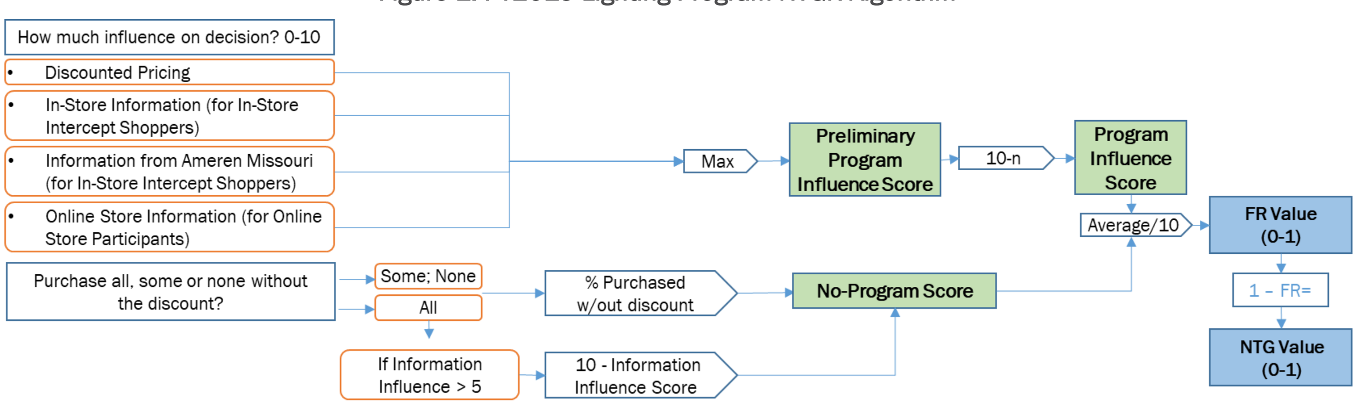
- A **Program Influence** component, based on the participant's perception of the program's influence on the decision to purchase LEDs instead of a less efficient bulb type; and
- A **No-Program** component, based on the participant's estimate of the number of LEDs he/she would have purchased in the absence of the in-store/online discount.

When scored, each component assesses the likelihood of FR on a scale of 0 to 10, with the two scores averaged and for a combined total FR score. FR is the mean of the two components:

$$Free\ Ridership\ (FR) = Mean(Program\ Influence, No\ Program\ Score)$$

As different and opposing biases potentially affect the two main components, the No-Program component typically indicates higher FR than the Program Influence component. Therefore, combining these decreases the biases. Figure 1 presents a diagram of the algorithm we used for to estimate FR using the self-report method. We asked similar questions of Online Store participants and customers interviewed through our in-store intercepts. Therefore, we were able to use the same algorithm to estimate FR for the two delivery channels.

Figure 1. PY2019 Lighting Program NTGR Algorithm



The Program Influence Score is assessed by asking respondents, on a scale from 0 (no influence) to 10 (a great deal of influence), about the importance of various program elements on their decision to purchase LEDs instead of less efficient light bulbs. For the upstream channel, we asked about the influence of the discounts, in-store information, and information they received elsewhere from Ameren Missouri. For the

Online Store we asked about the influence of the discounts as well as information they might have seen on the Online Store.

The Preliminary Program Influence Score equals the maximum influence rating across the relevant program elements rather than, for example, the mean influence rating across the program elements. This is based on the rationale that if any given program element had a great influence on the respondent's decision, then the program itself had a great influence, even if other elements had less influence. An inverse relationship occurs between high program influence and FR: the greater the program influence, the lower the FR. The Program Influence Score = 10 - Preliminary Program Influence Score.

The No-Program Score is used to estimate how many LEDs respondents would have purchased if Ameren Missouri did not discount LEDs. Respondents were offered the option of purchasing all, some, or none of the LEDs they purchased in the store. Respondents reporting that they would have purchased all the LEDs without the discounts should be considered free riders and receive a No-Program Score of 10. Those reporting they would have purchased none of the LED bulbs without the discounts were classified as non-free riders and received a No-Program Score of zero. Respondents who reported they would have purchased some of the LEDs without the discounts were assigned a No-Program Score between 0 and 10, reflective of the percentage of LEDs they would have purchased absent the program.

Respondents who reported they would have purchased all of the LEDs without the discounts, but also reported that information (either in-store, the Online Store, or other information from Ameren Missouri) had a moderate to high influence on their decision, had their No-Program Scores adjusted to equal the level of influence they attributed to these program-sponsored informational materials.

Table 10 shows the estimated FR rates for the Online Store overall and by bulb type purchased.[3] We find rather low FR rates for the Online Store across all bulb types though we find slightly higher FR for specialty LEDs.

Table 10. PY2019 Lighting Program Online Store Free-Ridership

Bulb Type	n	Free-Ridership (FR)	% Ex Post Gross
Standard LED	114	12.0%	73%
Reflector LED	44	13.1%	19%
Specialty LED	31	17.6%	8%
Weighted Total	**189**	**12.7%**	**100%**

Table 11 shows the estimated FR rates from the in-store intercepts for the upstream channel and by store type. Due to the small sample sizes for reflector and specialty LEDs, we do not provide results by bulb type. The FR rate for non-discount stores (32%) is almost three times higher than discount stores. The program included discount stores to attempt to reach more low-income customers who continue to face barriers to efficient lighting adoption. The lower FR rates for these stores suggest that the strategy is indeed reaching

[3] Note that for all the tables presented in this section, individual channel or bulb type results are weighted by ex post gross savings to derive the final totals.

customers who would have been less likely to purchase LEDs without the program. However, because savings from bulbs sold at discount stores only comprise 10% of upstream channel savings, overall channel FR from the self-report method is heavily weighted towards the non-discount FR estimate.

Table 11. PY2019 Lighting Program Upstream Free-Ridership: In-Store Intercepts

Bulb Type	n	Free-Ridership (FR)	% Ex Post Gross
Discount	76	12.3%	10%
Non-Discount	126	32.2%	90%
Weighted Total	**202**	**30.2%**	**100%**

FR for the upstream channel is greater than the Online Store. This difference could be due to several factors including differences in the types of customers that purchased LEDs through the Online Store versus at brick and mortar retailers, the information provided on the Online Store site, or differences in estimation methods.

We attempted to minimize differences in methods by asking similar questions of customers who purchased bulbs online and in-store. We also used the same algorithm to estimate FR. The FR for the Online Store and discount stores is quite similar suggesting that the customers may be similar in a way that impacts FR. We only asked demographic questions of Online Store participants so we cannot make any direct comparisons, however, Online Store customers tend to have moderate to high incomes so it is unlikely that customers are similar in terms of income, assuming discount store customer have lower incomes. We asked all customers what type of light bulbs they would be replacing with their new LEDs. We find that Online Store and discount store customers are both more likely to be replacing an incandescent compared to customers who purchased bulbs at a non-discount retailer. These results suggest that Online Store and discount customers may have lower efficient bulb saturations and need more encouragement to install efficient bulbs.

Price Elasticity Modeling

The price elasticity modeling approach to estimating NTG centers on the simple economic principle that a change in price causes a change in product sales. This assumption is at the core of the program theory, so measuring the effect of program discounts on bulb sales serves as a good indicator of a program's net impact. The price elasticity method models this relationship between product price and sales volume using the program sales data. The model estimates price elasticity, allowing for predictions of sales at various prices, namely, program-discounted and non-discounted price levels.

For the modeling effort to succeed, there must be sufficient price variation for identical products in the same store during the evaluation period. As the first step in our analysis, we thoroughly reviewed the presence of price variation by exploring. We analyzed variation within store location to account for pricing variation driven by locational differences, differences in pricing set by retailer, as well as demographic differences of the shoppers in the store's territory. Overall, 37% of unique models varied in price at least once of the course of the program year. Those models represented 79% of all PY2019 program sales. We observed consistent price variation by bulb type as well. More specifically, 51% of unique standard models, 31% of reflector models, and 41% of specialty models varied in price. Price varying models accounted for 59%, 41% and 48% of sales for standard, reflector, and specialty bulbs, respectively.

The program sales data extract reflects transaction-level sales summaries. Depending on the retailer and manufacturer, transaction periods ranged from 1 day to 2 months. Roughly half (48%) were weekly and a large majority (72%) were 7 days or less. To ensure time-series consistency and to maximize the potential for capturing the effect of discounts on bulb sales, we normalized transaction periods to a monthly level.

While the program provided discounts for certain products, the retailer sometimes added its own discount, sometimes on the same products affected by the program. This resulted in additional price variation that was beneficial for the regression modeling approach. The customer may not necessarily have been aware of the exact source of price discounts, but that is irrelevant when modeling the effect of price on sales volume. The theory behind this method isolates the actual price paid and the associated sales of the product at that price. However, at the simulation stage of the method, it is only appropriate to credit the program with sales associated with the discounts it provided.

To reach our final price elasticity estimates, we fit a series of fixed-effects models, fixing the store location, and predicting the sales volume from product price. We considered model fit indices, favoring models with larger R-squared values, lower Akaike's Information Criterion (AIC) values relative to other models based on the same products, and simpler models over more complex ones. As part of the modeling efforts, we also analyzed residual plots and tested for omitted variable bias. Table 12 summarizes a variety of models tested as part of the modeling effort along with associated core diagnostic parameters and the resulting price elasticity estimates. As can be seen in the table, we specified models with retailer and seasonal terms. Overall, the models were similar across core diagnostic metrics and yielded comparable elasticities. We chose the model with price and model predictors (Model 2 in the table below), primarily due to its simplicity and comparatively strong diagnostics. Using the model specification, we modeled demand elasticities by bulb type (standard, reflector, and specialty products).

Table 12. Tested Model Summary and Diagnostics

Model Number	Model Predictors	Adjusted R Squared	AIC	Price Elasticity Estimate	SE	P value
1	Price Only	0.05	131,784	-0.53	0.012	< 0.001
2	Price, Model	0.70	88,198	-0.42	0.012	< 0.001
3	Price, Channel	0.70	88,198	-0.42	0.012	< 0.001
4	Price, Season	0.70	88,116	-0.46	0.013	< 0.001
5	Price, Channel, Model, Season	0.70	88,116	-0.46	0.013	< 0.001
6	Price, Season, Model	0.70	88,075	-0.43	0.013	<0.001
7	Price, Months, Model	0.70	88,026	-0.44	0.014	<0.001

Equation 3 contains the final sales data model specification. As is common in this type of analysis, we used the log of both price and sales quantity, which greatly improves the distributions of those variables, and allows for the interpretation of the price coefficient as the percent increase in sales given a one percent decrease in price, simplifying the process of analyzing price elasticity and NTG.

Equation 3. Final Sales Data Model Specification

$$ln(Q_m) = \alpha + \beta_1 ln(P_m) + \sum_{\mu}(\beta_\mu model\ dummy_m)$$

Where:

- m = bulb model
- ln = natural log
- Q = quantity of bulbs sold
- P = price per bulb
- $model\ dummy$ = a vector of dummy variables equaling 1 for each unique model number, and 0 for all others
- β_1 = coefficient representing average price elasticity
- β_μ = a vector of coefficients representing each unique model number (m)
- α = constant

Using the modeled results, the evaluation team estimated sales at non-discounted prices using Equation 4. We used MSRP data supplied as part of the program sales data extract for estimates of non-discounted prices.

Equation 4. Price Elasticity Modeling Estimation of Sales Volume at Non-Discounted Prices

$$\widehat{Sales}_{wo} = Sales_w * \left(\frac{Price_{wo}}{Price_w}\right)^{PC}$$

Where:

- $\widehat{Sales}_{wo}$ = Estimated sales without discount (MSRP)
- $Sales_w$ = Sales with discount (actual sales)
- $Price_{wo}$ = Price without discount (MSRP)
- $Price_w$ = Price with discount (actual price)
- PC = Price coefficient

We excluded bulbs sold through the discount retailer channel from the price elasticity modeling due to a lack of price variation. We developed free-ridership (FR) for all other retail channels by comparing the predicted sales at non-discounted prices to the actual sales at program-discounted prices using Equation 5 below.

Equation 5. Price Elasticity Modeling FR Estimation Formula

$$FR = \frac{\widehat{Sales}_{wo}}{Sales_w} = \frac{Non - Discounted\ Sales}{Discounted\ Sales}$$

Where:

- FR= free-ridership
- $\widehat{Sales}_{wo}$= Estimated sales without discount (MSRP) in non-discount stores
- $Sales_w$= Sales with discount

As described above, we used regression modeling to estimate price elasticities. The elasticity curves show low to moderate sensitivity to changes in price. As can be seen in Figure 2, Figure 3, and Figure 4, LED price elasticity is -0.49 for Standard bulbs, -0.15 for Reflector bulbs, and -1.11 for Specialty bulbs. A price elasticity of -0.49 means that for every 1% increase in price, there is a 0.49% decrease in sales.

Figure 2. Price Elasticity Modeling: Standard Bulbs

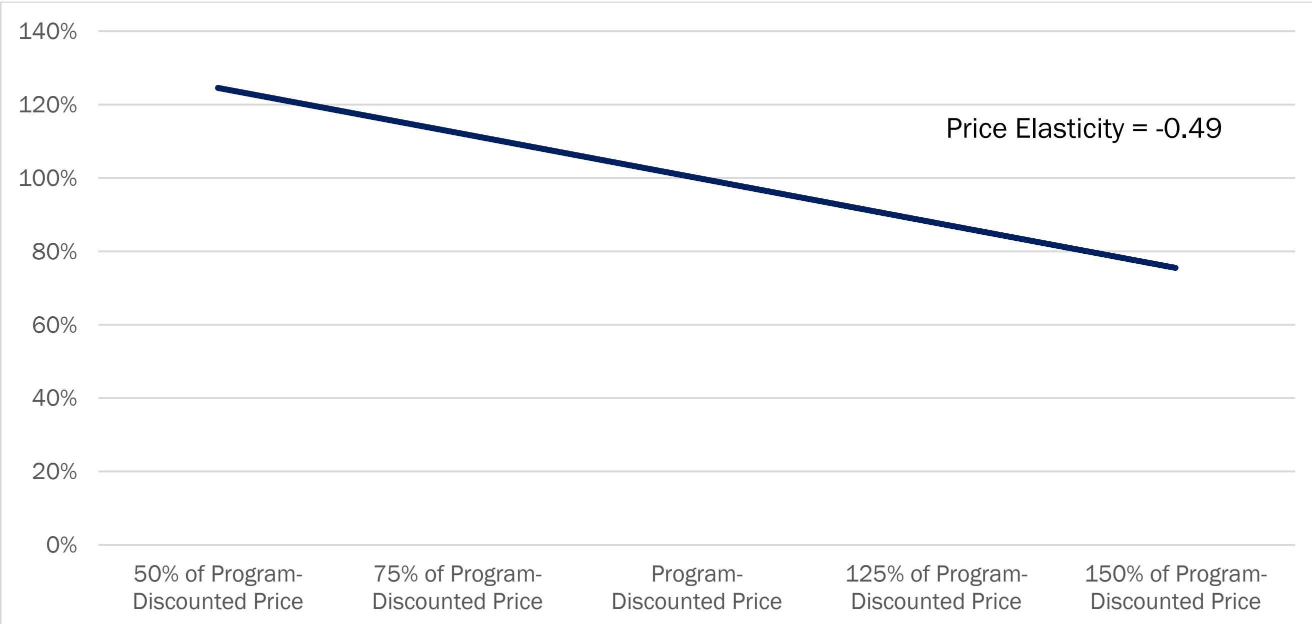


Figure 3. Price Elasticity Modeling: Reflector Bulbs

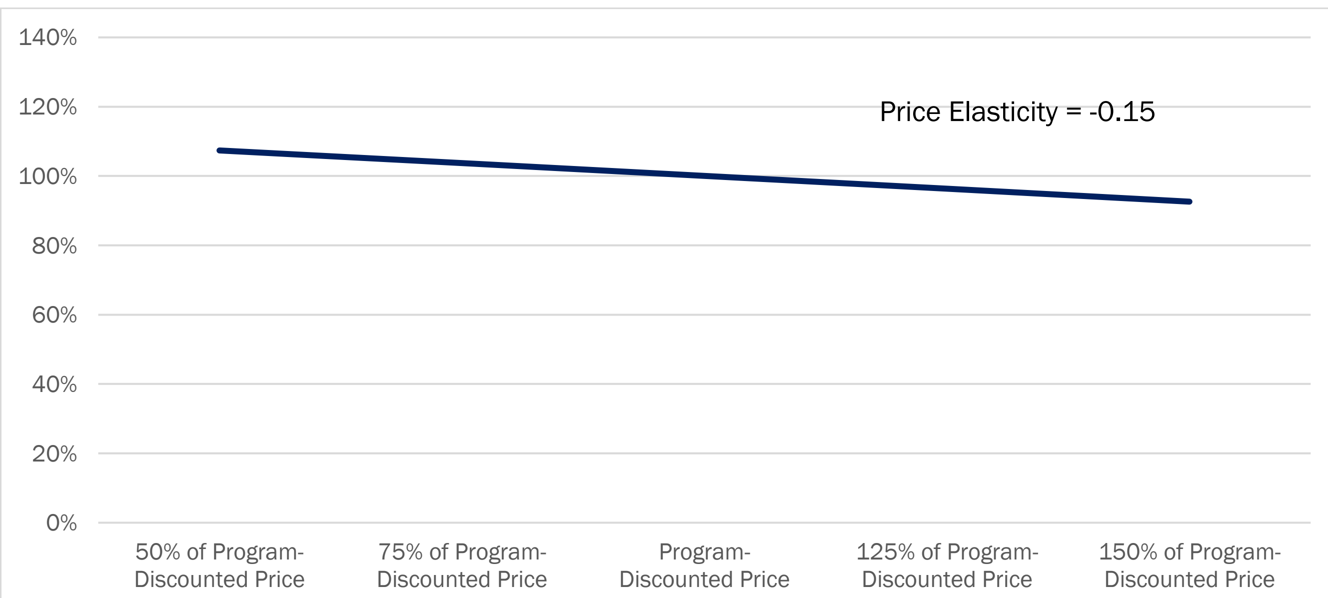
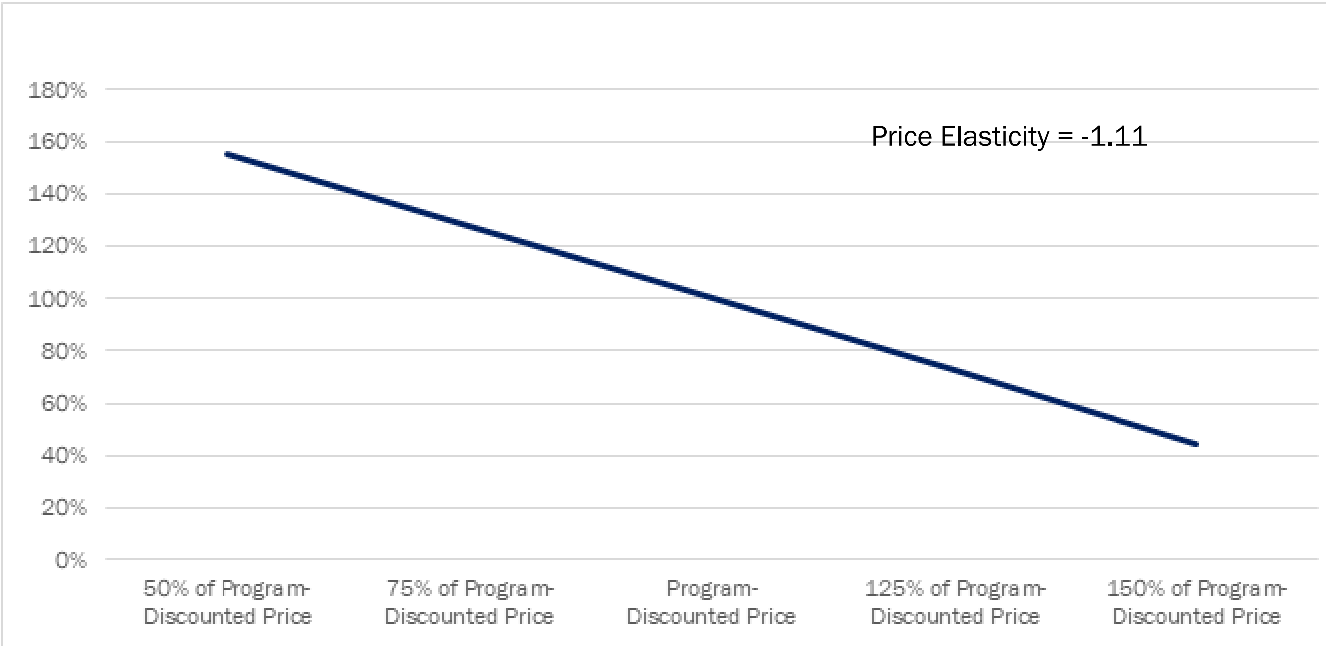


Figure 4. Price Elasticity Modeling: Specialty Bulbs



When compared to other lighting evaluations that made use of elasticity modeling, including the last evaluation of the program, and in light of recent changes in the lighting market, the price elasticities from our models appear reasonable. **Error! Not a valid bookmark self-reference.**summarizes lighting price elasticities from similar studies. As can be seen in the table, while price elasticities vary across the studies, the results of our analysis are within the range of the benchmarked values. In addition, the lighting market has been changing dramatically in recent years with LEDs dropping in price precipitously and becoming commonplace on retailer store shelves and in customers' homes. Finally, light bulbs are an essential and generally non-cyclical low-cost good. Such goods typically display lower elasticity of demand.

Table 13. Price Elasticity Estimates Benchmarking

Study	Study Method	Study Year	Price Elasticity
Ameren Missouri PY2018 Residential Lighting Evaluation	Demand elasticity modeling	2018-2019	-1.47 (Big Box stores, general purpose) -0.45 (Big Box, reflector) -1.06 (Big Box, decorative) -1.73 (Club stores) -1.97 (Small chain stores)
Duke Energy Carolinas and Progress Upstream Lighting Program Evaluation	Discrete choice modeling	2016	-0.27

Study	Study Method	Study Year	Price Elasticity
Efficiency Maine LED Lighting Pricing Trial	Pricing trial experiment	2017	-1.78 (standard LEDs) -0.76 (reflector LEDs)
California Statewide LED Latent Class Discrete Choice Study	Latent class discrete choice modeling	2018	-0.42 (Globe LEDs) -0.28 (Reflector LEDs)

Using the best-fitting sales data regression models, Opinion Dynamics estimated total sales volume at non-program-discounted price points for each of the modeled product types. Table 14 provides the price elasticity modeling outputs used to estimate FR.

Table 14. Price Elasticity Modeling Outputs

Parameter	Standard	Reflector	Specialty
Sales-weighted average discounted price	$0.87	$1.46	$0.99
Actual sales with program discount	1,942,079	310,062	194,200
Sales-weighted average non-discounted price	$2.51	$3.43	$2.94
Predicted sales at non-discounted prices	1,153,529	273,512	58,480

Using the model outputs, we estimated FR for each bulb type (Table 15). We developed an overall estimate of FR by weighting FR values for each bulb type by associated ex-post gross savings.

Table 15. PY2019 Lighting Program Upstream Free-Ridership: Price Elasticity Modeling

Bulb Type	FR	% Ex Post Gross Savings
Standard	59.4%	74%
Reflector	88.2%	18%
Specialty	30.1%	8%
Total	**62.5%**	**100%**

Final Lighting Program Free Ridership

The two upstream FR methods produced different results with the price elasticity modeling producing a result that is double that of the self-report method from the in-store interviews. Estimating what a customer would have hypothetically purchased if the program had not discounted LEDs is challenging. The benefit of having two methods of FR estimation is that we can leverage the strength of one method to make up for the weaknesses of the other. We provide additional detail on the strengths and weaknesses of each method in the sections below.

Price Elasticity Modeling Assessment

- Price elasticity modeling is based on a well-established economic theory that lowering product pricing increases product demand. Numerous factors can impact how responsive demand is to price changes, but by modeling the impact of LED price changes on LED sales, we can estimate LED sales with and without program discounts to estimate FR. Despite the strong theoretical foundation, estimating price elasticity models for upstream lighting programs still has some challenges. **Data coverage.** A strength of price elasticity modeling is that it is based on sales data from the entire year and nearly all retailers. Because there was no price variation at discount stores, we were unable to include those retailers in the analysis, but the modeled data comprised sales that accounted for 90% of gross savings from the upstream channel.

- A weakness of the method is that it only uses program sales data instead of full category lighting data. The theory underlying the model is that any lift in sales due to price reductions is a shift in sales from a less efficient product to an LED, which may or may not be the case given all the alternative products on the market. In fact, our in-store intercept results show that 38% of customers who purchased lighting products purchased non-discounted LEDs, many of which likely lack the ENERGY STAR rating and are therefore less expensive. We cannot be certain that absence the program discounts on ENERGY STAR LEDs that some customers would purchase these less expensive LEDs instead. **Extrapolation of model results.** A weakness of our particular elasticity modeling is that we do not have an estimate sales without program discounts. Therefore, we are extrapolating study results beyond the data used to estimate the model, which can bias the predicted results.
- **Omitted variable bias.** Modeling price as a predictor of sales does not take account of the effects of marketing and merchandising, such as advertising, product placement, and signage, which are also program interventions. Such information is rarely available to the evaluators and therefore is not ordinarily incorporated in the sales data modeling efforts. When the information is available, it can be challenging to incorporate since marketing promotions rarely match the monthly invoicing unit of analysis we use. It is likely that omitting predictors that would have an influence on sales beyond price results in those omitted "effects" being absorbed by the price variable thus inflating the price coefficient. We explored the severity of this bias through available data. Based on the 2019 in-store intercept results, just 15% of program LED purchasers reported learning about LEDs through Ameren Missouri marketing materials and another 7% through conversations with store representatives. Of those, close to a third (30%) reported not being influenced by program marketing in their purchase decision.[4] These results indicate that, while present, omitted variable bias from marketing likely has a limited impact on the results.
- **Price variation levels.** Price variation levels in the sales data can have an effect on free-ridership. In our past experience, we have found that free ridership and price variation are typically negatively correlated; we find higher free ridership when we have less price variation. While for this analysis, we had robust variation in pricing levels for a large majority of LEDs, it is possible that the level of variation can have a biasing effect of the free ridership estimate.

In-Store Intercepts Assessment

The in-store intercepts use the self-report survey method, which is a well-established method for estimating NTG for energy efficiency programs with known strengths and weaknesses. Given this long history, best practices exist to minimize error. Upstream lighting programs present a unique opportunity to make use of some best practices but also some challenges for others.

- **Real time data collection**. A strength using the methods in-store interviews at the time of purchase is that it allows us to hear in real time the factors that influenced the customer's purchase decision.

[4] A rating of 0 and 5 on a scale from 0 to 10, where 0 means no influence and 10 means a great deal of influence.

The customer has not had time to install and experience the product so the responses will not be biased by the post-purchase experience.

However, despite the in-store environment, we customers responses are still their best guess about what they would purchase if the LEDs they are buying cost more. We do not send them back to the shelf to pick another project. The response accuracy likely depends on how much time customers took making their product selection or how much they know and care about light bulbs, which is a relatively small and uninteresting purchase.

- **Social desirability bias.** The self-report method may be subject to social desirability bias if customers are reluctant to admit that they would not purchase the energy efficient version of a product if they had to pay full price. Internet surveys can help reduce this bias because they are self-administered. Because in-store interviews are conducted in person by a field interviewer, customers may be less likely to say they would not purchase an energy efficient bulb if it cost more.
- **Data coverage.** In-store intercepts are challenging and costly to conduct. Therefore, we make use of a convenience sample that limits our data collection to larger retailers in select locations and during limited time periods. As such, the results may not be representative of all program sales. To be cost effective, we typically only conduct intercepts at larger retailers with the greatest sales to maximize the number of interviews we complete in a day. An advantage of this approach is that our results represent the majority of program sales. However, the retailer that sold 51% of bulbs through the program in 2019 would not allow us to conduct research at their stores, which may have biased our results. We also conducted the research from October to December, during the time of the Program's special promotions that dramatically reduce bulb prices. It is possible that our FR estimates based on deeply discounted bulbs does not represent FR during the rest of the year.

Combined Free Ridership Method Results Given the challenges inherent with each method, we combined the results to produce an overall estimate of FR for the upstream channel (Table 16). First, we differentiated between discount and non-discount stores because they are so different, and we only had an estimate of FR from the self-report method because of lack of price variation.[5] For non-discount stores, we had FR estimates from both methods. We did not make a judgment about what technique might be better so we took a straight average of the intercept and sales data values. The store type level results were weighted by ex post gross savings to derive the overall upstream channel FR score of 43.8%.

Table 16. PY2019 Lighting Program Upstream Free-Ridership

Channel	Self-Report Free-Ridership	Price Elasticity Modeling Free-Ridership	Final Free-Ridership	% of Ex Post Gross Savings
Discount	12.3%	NA	12.3%	10%
Non-Discount	32.2%	62.5%	47.3%	90%
Weighted Total	**30.2%**	**62.5%**	**43.8%**	**100%**

We weighted the FR results for each program channel by ex post gross savings to produce an overall FR estimate of 43.7%, which is nearly identical to the upstream FR due to amount of savings from the upstream channel (Table 17).

[5] Note that price elasticity modeling requires variability in product prices by bulb type. No price variability was present across the discount stores, so they were not part of the price elasticity modeling effort.

Table 17. PY2019 Lighting Program Free-Ridership

Channel	Free-Ridership (FR)	Participant Spillover (PSO)	Non-Participant Spillover (NPSO)	NTGR (1-FR+PSO+NPSO)	% Ex Post Gross
Upstream	43.8%	0.0%	7.4%	63.6%	99.7%
Online	12.7%	2.6%	0.0%	89.9%	0.3%
Overall Program	**43.7%**	**0.0%**	**7.4%**	**63.7%**	**100.0%**

Participant Spillover

For participants who purchased lighting through the Online Store, we estimated PSO savings using the participant survey by asking the PSO survey battery that we used for other residential programs. The questions asked about additional energy efficiency home upgrades that the respondent may have took without receiving an incentive and the degree to which the program influenced their decision to make the upgrades. The questions covered non-lighting upgrades that a customer made after their lighting purchase because of their experience with the lighting or the program marketing. We used the methodology outlined in main volume of the Residential Report..

Dividing the estimated total PSO in our sample (1,207 kWh) by total program ex post gross savings of the overall participant sample (70,295 kWh) yields a PSO rate of 2.6%, as shown below:

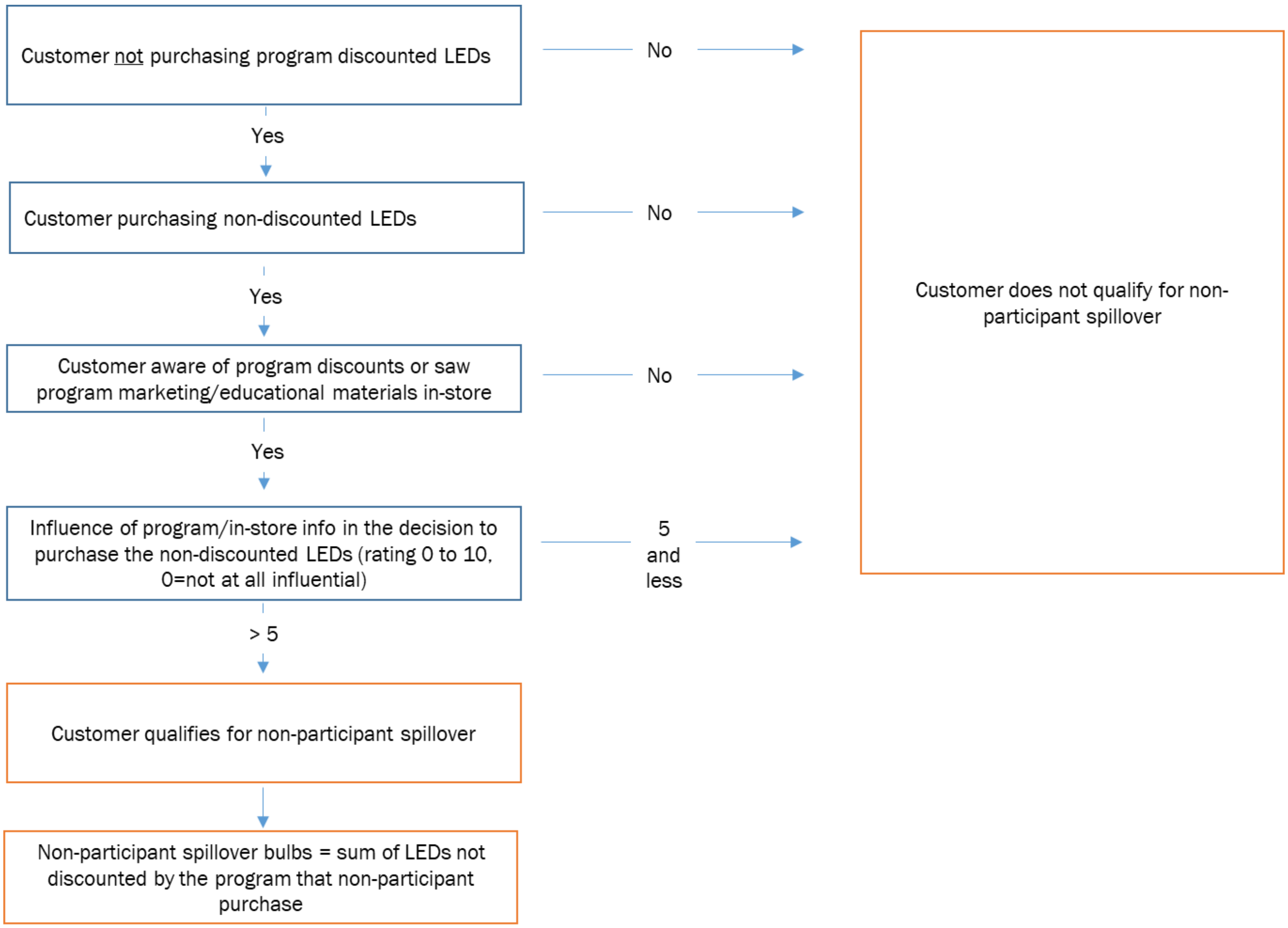
$$PSO\ \%_{Energy} = \frac{Total\ participant\ sample\ SO\ (kWh)}{Total\ participant\ sample\ savings\ (\text{kWh})} = \frac{1{,}207\ Wh}{70{,}295\ \text{kWh}} = 1.7\%$$

For the upstream channel, we interviewed customers as they were purchasing LEDs. Therefore, they did not have the opportunity to take additional actions based on their experience with the bulbs. However, customers could have purchased both program-discounted and non-discounted LEDs. That program purchase could have caused the customer purchase additional non-discounted LEDs resulting in PSO. During the intercept interview, we asked a series of questions to determine if any discounted LED purchases had influenced additional non-discounted purchases and found no PSO due to the upstream channel.

Non-Participant Spillover

For the upstream channel, we also used the intercepts to estimate NPSO. Figure 5 presents a diagram of the NPSO eligibility determination methodology used for this evaluation. In general, a respondent was eligible for NPSO when they purchased only non-discounted LEDs. Further, the respondent needed to be aware of the program discounts or saw program marketing/educational materials in-store. If these conditions were met, we then assessed the degree of influence the program material had on their purchase decision (using the 11-ppoint scale), and if rated higher than five, the respondent qualified for NPSO, which was the sum of the non-program LED savings they are purchasing.

Figure 5. Respondent Eligibility for Non-Participant Spillover



To supplement the numeric responses, the survey/intercept also contained open-ended questions about how the program influenced the decision to make the upgrades and why the participant made the installations without a program incentive. A respondent's additional energy efficiency installations were deemed eligible for NPSO if the open-ended responses did not contradict that the installations were eligible for NPSO.

To compute NPSO, we first found the ratio of respondents that had qualified for NPSO in our survey and the total number of respondents that had purchased any non-discounted LEDs (see Table 18). We then extrapolated the results the Ameren Missouri customer base based on the average number of spillover bulbs and the number of customers in the Ameren Missouri service territory. That number was then divided by the total number of program discounted bulbs from the entire upstream channel to come up with the final NPSO rate of 7.4%.

Table 18. PY2019 Lighting Program Upstream Channel Non-Participant Spillover

Calculation Input	Sample	Population
Total Customers	414	935,186
Non-participating customers purchasing non-discounted LEDs	208	469,852
Non-participating customers purchasing non-discounted LEDs influenced by the program	15	33,884
Average number of spillover bulbs per customer	5.9	
Total number of spillover bulbs	88	199,913
Total number of program discounted bulbs	2,716,116	
Non-Participant Spillover Rate	**7.4%**	

Residential Lighting Program NTGR

Table 19 shows the final computation of the NTGRs for the PY2019 Lighting Program. The upstream NTGR is lower (64%) than the Online Store (89.9%). However, because the upstream channel accounts for 99.7% of total program ex post gross, when weighting results the final NTGR of 63.7% closely mirrors the upstream rate.

Table 19. PY2019 Lighting Program Net-to-Gross Ratio Composition

Channel	Free-Ridership (FR)	Participant Spillover (PSO)	Non-Participant Spillover (NPSO)	NTGR (1-FR+PSO+NPSO)	% Ex Post Gross
Upstream	43.8%	0.0%	7.4%	63.6%	99.7%
Online	12.7%	2.6%	0.0%	89.9%	0.3%
Overall Program	**43.7%**	**0.0%**	**7.4%**	**63.7%**	**100.0%**

Heating Ventilation and Air Conditioning (HVAC)

Gross Impact Methodology

Air Source Heat Pump Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program air source heat pump (ASHP) measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 6. Air Source Heat Pump Energy and Demand Savings Equations (Replace on Fail)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 7. Air Source Heat Pump Energy and Demand Savings Equations (Early Replacement – First Six Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{DR \times SEER_{Exist}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Exist}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 8. Air Source Heat Pump Energy and Demand Savings Equations (Early Replacement – Next 12 Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Where:

$EFLH_{Cool}$ = Equivalent full load hours of air conditioning = 869

$EFLH_{Heat}$ = Equivalent full load hours of heating = 1,496

$Capacity_{Cool}$ = Cooling capacity of air source heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

$Capacity_{Heat}$ = Heating capacity of air source heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

Table 20. $Capacity_{Cool}$ and $Capacity_{Heat}$ for Air Source Heat Pump Measures

Measure	$Capacity_{Cool}$ (Btu/hr)	$Capacity_{Heat}$ (Btu/hr)
ASHP SEER 15 ER Elec Resist Furnace ER	34,800	34,800
ASHP ER with ASHP SEER 15 ER	35,160	35,160
ASHP SEER 15 Replace at Fail Elect Resist Furnace	34,320	34,320
ASHP SEER 16+ ER Elec Resist Furnace ER	38,160	38,160
ASHP ER with ASHP 16+ ER	37,800	37,800
ASHP SEER 16+ Replace at Fail Elec Resist Furnace	37,320	37,320
ASHP SEER 15 ER Air Source Heat Pump MF	37,200	37,200
ASHP SEER 15 ER Elec Resist Furnace MF	33,600	33,600
ASHP SEER 16+ Replace at Fail Elec Resist Furnace MF	38,400	38,400
ASHP SEER 16+ ER Elec Resist Furnace MF	37,200	37,200
ASHP 18+ Replace at Fail Elec Resist Furnace	33,600	33,600
ASHP SEER 18+ Replace at Fail Elec Resist Furnace MF	33,600	33,600
ASHP 18+ replace ASHP ER	39,600	39,600
ASHP SEER 18+ ER Elec Resist Furnace	37,200	37,200
ASHP SEER 18 ER Elec Resist Furnace MF	37,200	37,200

$SEER_{Base}$ = Seasonal Energy Efficiency Ratio of baseline cooling system (kBtu/kWh) = 14 if replacing ASHP, 13 if replacing central air conditioner (CAC)

$HSPF_{Base}$ = Heating Seasonal Performance Factor of baseline heating system (kBtu/kWh) = 8.2 if replacing ASHP, 3.41 if replacing electric resistance

$SEER_{Exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh) = Actual from program tracked data, de-rated by equipment age; if unknown, assumed 8.33

$HSPF_{Exist}$ = Heating Seasonal Performance Factor of existing heating system (kBtu/kWh) = Actual from program tracked data; if unknown, assumed 6.58 if replacing ASHP, 3.41 if replacing electric resistance

$SEER_{EE}$ = Seasonal Energy Efficiency Ratio of efficient air source heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Appendix F (November 2019)

$HSPF_{EE}$ = Heating Seasonal Performance Factor of efficient air source heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Appendix F (November 2019)

Table 21. $SEER_{EE}$ and $HSPF_{EE}$ for Air Source Heat Pump Measures

Measure	$SEER_{EE}$	$HSPF_{EE}$
ASHP SEER 15 ER Elec Resist Furnace ER	15.11	8.67
ASHP ER with ASHP SEER 15 ER	15.12	8.75
ASHP SEER 15 Replace at Fail Elect Resist Furnace	15.11	8.66
ASHP SEER 16+ ER Elec Resist Furnace ER	16.00	9.35
ASHP ER with ASHP 16+ ER	16.00	9.33
ASHP SEER 16+ Replace at Fail Elec Resist Furnace	16.00	9.43
ASHP SEER 15 ER Air Source Heat Pump MF	15.10	8.70
ASHP SEER 15 ER Elec Resist Furnace MF	15.10	8.70
ASHP SEER 16+ Replace at Fail Elec Resist Furnace MF	16.00	9.70
ASHP SEER 16+ ER Elec Resist Furnace MF	16.00	9.40
ASHP 18+ Replace at Fail Elec Resist Furnace	18.00	9.70
ASHP SEER 18+ Replace at Fail Elec Resist Furnace MF	18.00	9.70
ASHP 18+ replace ASHP ER	18.00	9.50
ASHP SEER 18+ ER Elec Resist Furnace	18.00	9.40
ASHP SEER 18 ER Elec Resist Furnace MF	18.00	9.40

DR = Derating factor, to account for performance degradation of existing equipment compared to its nameplate rating. DR = $(1\text{-}1.44\%)^{Age}$, where “Age” is the age of the existing equipment in years (default = 12 years). We did not de-rate existing equipment with nameplate efficiency of 8 SEER or lower.

HF = Household factor, to adjust heating consumption for non-single-family households = 100% if single-family, 65% if multi-family

CF = Coincidence factor = 0.0009474181

Ductless Minisplit Heat Pump Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program ductless minisplit heat pump measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 9. Ductless Minisplit Heat Pump Energy and Demand Savings Equations (Replace on Fail)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 10. Ductless Minisplit Heat Pump Energy and Demand Savings Equations (Early Replacement – First Six Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{DR \times SEER_{Exist}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Exist}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 11. Ductless Minisplit Heat Pump Energy and Demand Savings Equations (Early Replacement – Next 12 Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Where:

$EFLH_{Cool}$ = Equivalent full load hours of air conditioning = 635

$EFLH_{Heat}$ = Equivalent full load hours of heating = 1,034 if ductless ASHP measure, 0 if ductless AC measure

$Capacity_{Cool}$ = Cooling capacity of heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

$Capacity_{Heat}$ = Heating capacity of heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

Table 22. $Capacity_{Cool}$ and $Capacity_{Heat}$ for Ductless Minisplit Heat Pump Measures

Measure	$Capacity_{Cool}$ (Btu/hr)	$Capacity_{Heat}$ (Btu/hr)
Ductless AC - ER SF	18,000	0
Ductless AC - ROF SF	18,000	0
Ductless ASHP - ROF SF	18,000	18,000
Ductless ASHP Replace Electric Resistance ER	18,000	18,000
Ductless ASHP Replace Electric Resistance ROF	19,200	19,200
Ductless ASHP ER	18,000	18,000

$SEER_{Base}$ = Seasonal Energy Efficiency Ratio of baseline cooling system (kBtu/kWh) = 14 if replacing ductless ASHP, 13 if replacing ductless AC

$HSPF_{Base}$ = Heating Seasonal Performance Factor of baseline heating system (kBtu/kWh)

Table 23. $HSPF_{Base}$ for Ductless Minisplit Heat Pump Measures

Measure	$HSPF_{Base}$
Ductless AC - ER SF	0
Ductless AC - ROF SF	0
Ductless ASHP - ROF SF	8.20
Ductless ASHP Replace Electric Resistance ER	3.412
Ductless ASHP Replace Electric Resistance ROF	3.412
Ductless ASHP ER	6.58

$SEER_{Exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh) = Actual from program tracked data, de-rated by equipment age; if unknown, assumed defaults from Appendix F (November 2019)

Table 24. $SEER_{Base}$ for Ductless Minisplit Heat Pump Measures

Measure	$SEER_{Base}$
Ductless AC - ER SF	6.3
Ductless AC - ROF SF	6.3
Ductless ASHP - ROF SF	7.2
Ductless ASHP Replace Electric Resistance ER	6.8
Ductless ASHP Replace Electric Resistance ROF	6.8
Ductless ASHP ER	7.2

$HSPF_{Exist}$ = Heating Seasonal Performance Factor of existing heating system (kBtu/kWh) = Actual from program tracked data; if unknown, assumed 5.44 if replacing ductless ASHP, 3.412 if replacing electric resistance

$SEER_{EE}$ = Seasonal Energy Efficiency Ratio of efficient heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Appendix F (November 2019)

$HSPF_{EE}$ = Heating Seasonal Performance Factor of efficient heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Appendix F (November 2019)

Table 25. $SEER_{EE}$ and $HSPF_{EE}$ for Ductless Minisplit Heat Pump Measures

Measure	$SEER_{EE}$	$HSPF_{EE}$
Ductless AC - ER SF	23.17	0
Ductless AC - ROF SF	23.17	0
Ductless ASHP - ROF SF	19	10.6
Ductless ASHP Replace Electric Resistance ER	22.63	11.4
Ductless ASHP Replace Electric Resistance ROF	22.77	11.4
Ductless ASHP ER	27.01	12.6

DR = Derating factor, to account for performance degradation of existing equipment compared to its nameplate rating. DR = $(1\text{-}1.44\%)^{Age}$, where "Age" is the age of the existing equipment in years (default = 12 years). We did not de-rate existing equipment with nameplate efficiency of 8 SEER or lower.

HF = Household factor, to adjust heating consumption for non-single-family households = 100%

CF = Coincidence factor = 0.0009474181

Ground Source Heat Pump Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program ground source heat pump measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 12. Ground Source Heat Pump Energy and Demand Savings Equations (Replace on Fail)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 13. Ground Source Heat Pump Energy and Demand Savings Equations (Early Replacement – First Six Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{DR \times SEER_{Exist}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Exist}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Equation 14. Ground Source Heat Pump Energy and Demand Savings Equations (Early Replacement – Next 12 Years)

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000} \times HF$$

$$kWh_{Heating} = \frac{\left(EFLH_{Heat} \times Capacity_{Heat} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{EE}}\right)\right)}{1000} \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Where:

$EFLH_{Cool}$ = Equivalent full load hours of air conditioning = 869

$EFLH_{Heat}$ = Equivalent full load hours of heating = 1,496

$Capacity_{Cool}$ = Cooling capacity of heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

$Capacity_{Heat}$ = Heating capacity of heat pump (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

Table 26. $Capacity_{Cool}$ and $Capacity_{Heat}$ for Ground Source Heat Pump Measures

Measure	$Capacity_{Cool}$ (Btu/hr)	$Capacity_{Heat}$ (Btu/hr)
GSHP SEER 14+ Replace Elec Resist Furnace	47,760	47,760
GSHP SEER 14+ ER Elec Resist Furnace ER	46,320	46,320
GSHP - 23 EER ER	50,400	50,400
GSHP - 23 EER NC	47,160	47,160
GSHP - 23 EER Replace at Fail	47,160	47,160

$SEER_{Base}$ = Seasonal Energy Efficiency Ratio of baseline cooling system (kBtu/kWh) = 14.1

$HSPF_{Base}$ = Heating Seasonal Performance Factor of baseline heating system (kBtu/kWh) = 10.58 if replacing heat pump, 3.41 if replacing electric resistance

$SEER_{Exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh) = Actual from program tracked data, de-rated by equipment age; if unknown, assumed 12 if replacing heat pump, 6.54 if replacing central air conditioner

$HSPF_{Exist}$ = Heating Seasonal Performance Factor of existing heating system (kBtu/kWh) = Actual from program tracked data; if unknown, assumed 9.55 if replacing heat pump, 3.41 if replacing electric resistance

$SEER_{EE}$ = Seasonal Energy Efficiency Ratio of efficient ground source heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Appendix F (November 2019)

Table 27. $SEER_{EE}$ for Ground Source Heat Pump Measures

Measure	$SEER_{EE}$
GSHP SEER 14+ Replace Elec Resist Furnace	28.0
GSHP SEER 14+ ER Elec Resist Furnace ER	28.1
GSHP - 23 EER ER	28.0
GSHP - 23 EER NC	28.0
GSHP - 23 EER Replace at Fail	28.0

$HSPF_{EE}$ = Heating Seasonal Performance Factor of efficient ground source heat pump (kBtu/kWh) = Actual from program tracked data; if unknown, assumed 15.14

DR = Derating factor, to account for performance degradation of existing equipment compared to its nameplate rating. DR = $(1\text{-}1.44\%)^{Age}$, where “Age” is the age of the existing equipment in years (default = 12 years). We did not de-rate existing equipment with nameplate efficiency of 8 SEER or lower.

HF = Household factor, to adjust heating consumption for non-single-family households = 100% if single-family, 65% if multi-family

CF = Coincidence factor = 0.0009474181

Central Air Conditioner Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program CAC measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 15. Central Air Conditioner Energy and Demand Savings Equations (Replace on Fail)

$$kWh = \left[\frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000}\right] \times HF$$

$$kW = kWh \times CF$$

Equation 16. Central Air Conditioner Energy and Demand Savings Equations (Early Replacement – First Six Years)

$$kWh = \left[\frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{DR \times SEER_{Exist}} - \frac{1}{SEER_{EE}}\right)\right)}{1000}\right] \times HF$$

$$kW = kWh \times CF$$

Equation 17. Central Air Conditioner Energy and Demand Savings Equations (Early Replacement – Next 12 Years)

$$kWh = \left[\frac{\left(EFLH_{Cool} \times Capacity_{Cool} \times \left(\frac{1}{SEER_{Base}} - \frac{1}{SEER_{EE}}\right)\right)}{1000}\right] \times HF$$

$$kW = kWh \times CF$$

Where:

$EFLH_{Cool}$ = Equivalent full load hours of air conditioning = 869

$Capacity_{Cool}$ = Cooling capacity of CAC (Btu/hr) = Actual from program tracked data; if unknown, assumed defaults from Appendix F (November 2019)

Table 28. $Capacity_{Cool}$ for Central Air Conditioner Measures

Measure	$Capacity_{Cool}$ (Btu/hr)
CAC SEER 15 ER / CAC SEER 15 ER Cold Weather	39,240
CAC SEER 15 Replace at Fail	39,240
CAC SEER 15 ER MF / CAC SEER 15 ER Cold Weather MF	24,000
CAC SEER 15 Replace at Fail MF	24,000
CAC SEER 16+ ER / CAC SEER 16 ER Cold Weather	36,720
CAC SEER 16+ Replace at Fail	35,880
CAC SEER 16+ ER MF / CAC SEER 16 ER Cold Weather MF	24,000
CAC SEER 16+ Replace at Fail MF	24,000
CAC SEER 17+ ER / CAC SEER 17+ ER Cold Weather	36,720
CAC SEER 17+ RAF	35,880
CAC SEER 17+ ER MF	24,000
CAC SEER 17+ RAF MF	24,000

$SEER_{Exist}$ = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh) = Actual from program tracked data, de-rated by equipment age; if unknown, assumed 8.33

$SEER_{Base}$ = Seasonal Energy Efficiency Ratio of baseline equipment (kBtu/kWh) = 13

$SEER_{EE}$ = Seasonal Energy Efficiency Ratio of efficient CAC (kBtu/kWh) = Actual from program tracked data; if unknown, assumed defaults in Ameren Missouri TRM Appendix F (November 2019)

Table 29. $SEER_{EE}$ for Central Air Conditioner Measures

Measure	$SEER_{EE}$
CAC SEER 15 ER / CAC SEER 15 ER Cold Weather	15.16
CAC SEER 15 Replace at Fail	15.13
CAC SEER 15 ER MF / CAC SEER 15 ER Cold Weather MF	15.00
CAC SEER 15 Replace at Fail MF	15.00
CAC SEER 16+ ER / CAC SEER 16 ER Cold Weather	16.36
CAC SEER 16+ Replace at Fail	16.37
CAC SEER 16+ ER MF / CAC SEER 16 ER Cold Weather MF	16.00
CAC SEER 16+ Replace at Fail MF	16.00
CAC SEER 17+ ER / CAC SEER 17+ ER Cold Weather	17.00
CAC SEER 17+ RAF	17.00
CAC SEER 17+ ER MF	17.00
CAC SEER 17+ RAF MF	17.00

DR = Derating factor, to account for performance degradation of existing equipment compared to its nameplate rating. DR = $(1\text{-}1.44\%)^{Age}$, where "Age" is the age of the existing equipment in years (default = 12 years). We did not de-rate existing equipment with nameplate efficiency of 8 SEER or lower.

HF = Household factor, to adjust heating consumption for non-single-family households = 100%

CF = Coincidence factor = 0.0009474181

Electronically Commutated Motor Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program electronically commutated motor (ECM) measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 18.

Equation 18. ECM Energy and Demand Savings Equations

$$kWh = kWh_{Heating\ Mode} + kWh_{Cooling\ Mode} + kWh_{Auto\ Circulation} + kWh_{Continuous\ Circulation}$$

$$kWh_{Heating\ Mode} = (1 - \%\ with\ New\ ASHP) \times \left(400\frac{kWh}{year} \times \frac{EFLH_{Heat}}{WI\ EFLH_{Heat}}\right)$$

$$kWh_{Cooling\ Mode} = (1 - \%\ with\ New\ Central\ Cooling) \times \left(70\frac{kWh}{year} \times \frac{EFLH_{Cool}}{WI\ EFLH_{Cool}}\right)$$

$$kWh_{Auto\ Circulation} = \left(25\frac{kWh}{year} \times \frac{EFLH_{Cool}}{WI\ EFLH_{Cool}}\right) + \left(2960\frac{kWh}{year} \times RT\right) - 30\frac{kWh}{year}$$

$$kWh_{Continuous\ Circulation} = \left(25\frac{kWh}{year} \times \frac{EFLH_{Cool}}{WI\ EFLH_{Cool}}\right) + \left(2960\frac{kWh}{year} \times RT\right) - 30\frac{kWh}{year}$$

$$kW = kWh \times CF$$

Where:

% with New ASHP = 16.34%

400 = Wisconsin heating savings (kWh/year)

$EFLH_{Heat}$ = Effective full load heating hours = 2,009

WI $EFLH_{Heat}$ = Wisconsin effective full load heating hours = 2,545.25

% with New Central Cooling = 80.14%

70 = Wisconsin cooling savings (kWh/year)

$EFLH_{Cool}$ = Effective full load cooling hours = 1,215

WI $EFLH_{Cool}$ = Wisconsin effective full load cooling hours = 542.50

25 = Cooling savings for all systems (kWh/year)

2,960 = Wisconsin circulation savings (kWh/year)

RT = Percent additional run time factor = 8.81%

30 = Standby losses (kWh/year)

CF = Coincidence factor = 0.0004660805

Advanced Thermostat Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential HVAC Program advanced thermostat measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 19.

Equation 19. Advanced Thermostat Energy and Demand Savings Equations

$$kWh = kWh_{Heating} + kWh_{Cooling}$$

$$kWh_{Heating} = \%ElectricHeat \times HeatingConsumption_{Electric} \times HF \times HeatingReduction \times ISR + (\Delta Therms \times Fe \times 29.3)$$

$$kWh_{Cooling} = \%AC \times \left(\frac{EFLH_{Cool} \times CapacityCool \times \frac{1}{SEER}}{1000} \right) \times CoolingReduction \times ISR$$

$$\Delta Therms = \%FossilHeat \times HeatingConsumption_{Gas} \times HF \times HeatingReduction \times ISR$$

$$kW = kWh_{Cooling} \times CF$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric = 100% if electric heating system; 0% if natural gas heating; 16% if unknown

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes, in kWh

Table 30. $HeatingConsumption_{Electric}$ for Advanced Thermostat Measures

Heating Equipment	$HeatingConsumption_{Electric}$
Electric Heat Pump	8,355
Electric Resistance	14,202
Natural Gas System	0
Unknown	11,456

HF = Household factor, to adjust heating consumption for non-single-family households = 100% if single-family, 65% if multi-family

HeatingReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat = 6.67%

ISR = In-service rate = 100%

ΔTherms = Therm savings if natural gas heating system, calculated using equation defined above

Fe = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

29.3 = Conversion factor of kWh per therm

%AC = Fraction of customers with thermostat-controlled air conditioning = 100%

EFLHCool = Equivalent full load hours of air conditioning = 869

CapacityCool = Capacity of air cooling system in Btu/hr = 36,552

SEER = Seasonal Energy Efficiency Ratio rating of the cooling equipment in kBtu/kWh = 13.55

1/1000 = Conversion factor of kBtu per Btu

CoolingReduction = Assumed percentage reduction in total household cooling energy consumption due to advanced thermostat = 8.0%

%FossilHeat = percentage of heating savings assumed to be natural gas = 0% if electric heating system; 100% if natural gas heating; 84% if unknown

HeatingConsumptionGas = Estimate of annual household heating consumption for gas-heated single-family homes, in therms = 682

CF = Coincidence factor = 0.0009474181

Desk Review Sample Design and Results Extrapolation Methodology

We developed a sample of CAC and ASHP projects to support engineering desk reviews. The subsections that follow describe the evaluation team's methodology for developing stratified random samples and extrapolating savings to the participant populations that received those measures.

Determination of Strata Boundaries Using the Dalenius-Hodges Method

We used the Dalenius-Hodges method to determine boundaries for each stratum. The method begins with the creation of numerous and narrow strata. Within each stratum, the frequency of coupons, f(y), is calculated. Next, the square root of f(y), $\sqrt{f(y)}$, is calculated and the cumulative of $\sqrt{f(y)}$ is formed. The total cumulative $\sqrt{f(y)}$ is then divided by the number of desired strata to determine the division points on the cumulative $\sqrt{f(y)}$ scale.

The above rule assumes equal widths, d, for the class intervals, and must be modified when the class intervals have variable widths dy. The approach recommended by Kish[6] is to multiply the f(y) by the width of the interval, take the square root of this value, and cumulate the values $\sqrt{d_y f(y)}$. Finally, as in the above case, the total of cumulative $\sqrt{d_y f(y)}$ is then divided by the number of desired strata to determine the division points on the cumulative $\sqrt{d_y f(y)}$ scale.

Optimal Allocation Using the Neyman Allocation Method

Once we determined strata boundaries, we employed the Neyman method to estimate the number to include in each stratum. Using this method, we estimated the population mean with the lowest variance for a fixed total sample size n under stratified random sampling. This allocation scheme, as described in Cochran,[7] follows the equation:

$$n_h = n \frac{N_h s_h}{\sum N_h s_h}$$

Where:

Nh = the total number of units in stratum h

nh = the number of units in the sample of stratum h

n = the total number of units in the sample across all strata

sh = the variance within stratum h

This formula for optimal allocation may produce an nh in some stratum that is larger than the corresponding Nh. This problem can arise in the plan for the verification of rebate program savings since the overall sampling fraction is large, and some strata have more variation than others. If the original allocation gives, for example, a n1 that is greater than N1, then we revise the equation referenced above as follows:

[6] Kish, L. (1995). *Survey Sampling.* Wiley Classics Library Edition.

[7] Cochran, W. G. (1977). *Sampling Techniques.* Hoboken: John Wiley & Sons, Inc.

$$n_h = (n - N_1)\frac{N_h s_h}{\sum_2^L N_h s_h}$$

If the original allocation gives, for example, an n1 that is greater than N1 and an n2 that is greater than N2, we revised the equation as follows:

$$n_h = (n - N_1 - N_2)\frac{N_h s_h}{\sum_3^L N_h s_h}$$

Using the approach, we expected the sample design for both CACs and ASHPs to provide statistically valid impact results within the 90% confidence level with ±10% relative precision for the projects overall based on demand.

Stratified Ratio Estimator Adjustment Method

We used the following approach to extrapolate results from the sampled projects back to the overall population for CACs and ASHPs.

$$r_{strc} = \frac{\bar{y}_{str}}{\bar{x}_{str}}$$

Where:

$r_{strc} =$ stratified-combined ratio of ex post to ex ante sample estimates, or realization rate

$\bar{y}_{str} =$ stratified sample ex post mean

$\bar{x}_{str} =$ stratified sample ex ante mean

The variance of the ratio is given by:

$$Var(r_{strc}) = \left(\frac{1}{N^2\overline{X}^2}\right)\sum_{h=1}^{L}\frac{N_h^2(N_h - n_h)}{n_h(N_h - 1)}\sigma_{hz}^2$$

$N_h =$ Number of participants in population of stratum h

$n_h =$ Number of participants in sample of stratum h

$\bar{y}_h =$ Estimated ex post sample mean in stratum h

$\bar{x}_h =$ Estimated ex ante sample mean in stratum h

And

$$\sigma_{hz}^2 = \sigma_{hy}^2 + R^2\sigma_{hx}^2 - 2R\rho_{hxy}\sigma_{hy}\sigma_{hx}$$

Where:

R = Ratio or realization rate

$\hat{\sigma}_{hy}^2 =$ Estimated variance of the ex post savings in stratum h

$\hat{\sigma}_{hx}^2 =$ Estimated variance of the ex ante savings in stratum h

$\hat{\rho}_{hxy} =$ Estimated correlation between X and Y in stratum h

The standard error is calculated as the square root of the variance.

Net Impact Methodology

Participant Free Ridership

The free ridership (FR) assessment consists of two components:

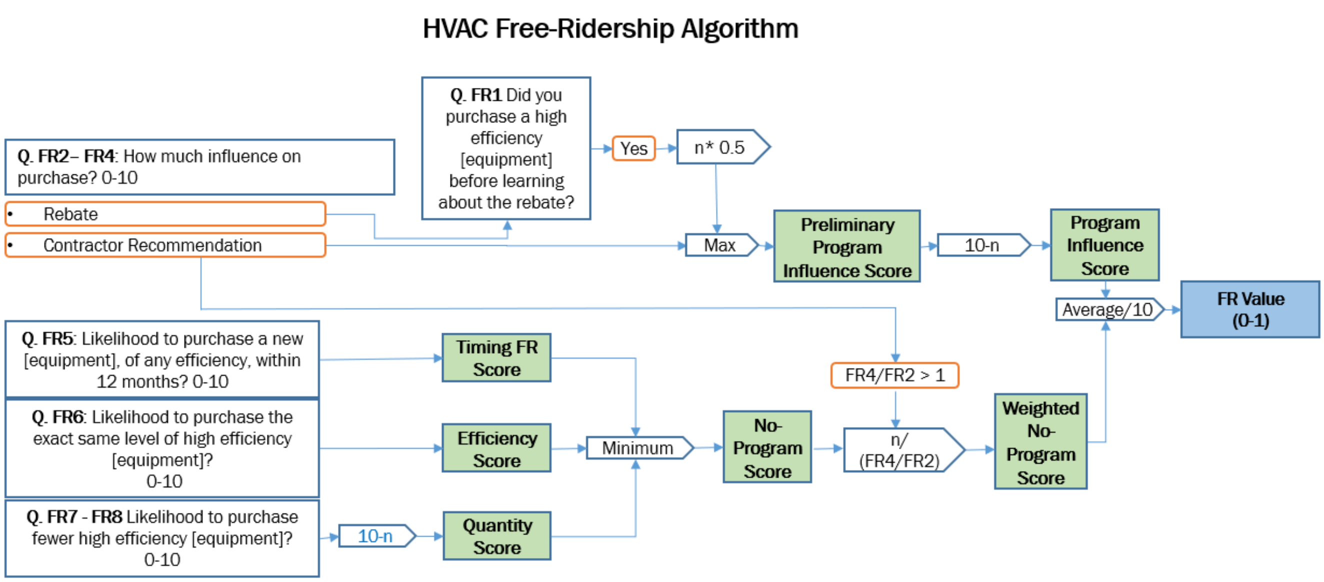
- A Program Influence component, based on the participant's perception of the program's influence on their decision to carry out the energy-efficient project; and
- A No-Program component, based on the participant's intention to carry out the energy-efficient project without program funds.

When scored, each component assesses the likelihood of FR on a scale of 0 to 10, with the two scores averaged and for a combined total FR score. FR is the mean of the two components:

$$Free\ Ridership\ (FR) = \ Mean(Program\ Influence, No\ Program\ Score)$$

As different and opposing biases potentially affect the two main components, the No-Program component typically indicates higher FR than the Program Influence component. Therefore, combining these decreases the biases. Figure 6 presents a diagram of the FR algorithm we used, including references to question numbers.

Figure 6. HVAC Program Free Ridership Algorithm



Calculation of the Program Influence Score

We assessed program influence by asking participant survey respondents, on a scale from 0 (not at all influential) to 10 (extremely influential), how important they found various program elements to be when deciding to purchase the high efficiency measure. Elements include potential influences on customer decision making such as rebates and contractor recommendations.

In addition to asking about specific program influences, we asked respondents whether they purchased a high-efficiency version of the equipment before learning of the rebate through the HVAC Program. Respondent's rating of the rebate's influence is adjusted by 0.5 for those answering the question "yes."

The Preliminary Program Influence (PI) Score equals the maximum influence rating for any program element rather than, for example, the mean influence rating. We based this on the rationale that if any given program element had a great influence on the respondent's decision, then the program itself had a great influence, even if other elements had less influence. An inverse relationship occurs between high PI and FR: the greater the PI, the lower the FR. The PI Score = 10 - Preliminary PI Score.

Calculation of the No-Program Score

We based the No-Program (NP) Score on three measures of the likelihood that a participant purchasing the exact same item(s) at the same time in the absence of the program. We assessed each of these likelihood measures on a 0-10 scale, where 0 means "not at all likely" and 10 means "very likely."

First, we asked the participant about the likelihood they would purchase an item of *any efficiency* within 12 months for the Timing (T) Score. Participants who were influenced by the program rebate to replace still-functioning equipment will likely give a low score to this question, while participants who needed to replace burned out equipment will give a high score.

Next, we asked the respondent to gauge the likelihood that they would purchase the same level of high efficiency equipment had the program rebate not been available. This measure forms the Efficiency (E) Score. We assigned an E Score of 5 to a respondent stating the likelihood of purchasing the same exact item as a 5 on a scale of 0 to 10. Additionally, if the respondent purchased multiple quantities of an item, we asked that respondent about the likelihood that they would have purchased fewer energy-efficient items. We subtracted the response to this question from 10 to compute the Quantity (Q) Score.

The NP Score is the minimum of the Timing, Efficiency, and (if applicable) Quantity Scores.

$$No\ Program\ Score\ (NP) = Min(T, E, Q)$$

Finally, we averaged the NP Score with the PI Score to calculate the final FR Value.

Consistency Checks

To address the possibility of conflicting responses (i.e., low intention score and high influence score), we included a consistency check in the survey that asked participants an open-ended question to address the program's influence. For example:

- How did the rebate from the Ameren Missouri Power to Save Heating and Cooling Program influence your decision to purchase your new <insert measure>?

We assessed the response to this open-ended question and its consistency with the other questions, and, if warranted—based on clear additional information—adjusted the score based on expert judgement.

Free Ridership Results

We calculated FR at the measure level for the HVAC program, using a total of 654 responses in the analysis for air conditioners, heat pumps, and advanced thermostats.[8] Heat pumps had the highest FR (42.1%), advanced thermostats (38.8%), and CACs (36.8%).

Participants' FR-related survey responses show the following:

- **Rebate Influence**: On average, participants said the rebate had a slightly more influence in their decision to purchase high efficiency CACs than heat pumps (7.1 vs. 6.6). Participants with advanced thermostats gave the lowest influence rating (5.6).
  - **Program Awareness:** Approximately 37% of participants purchased their HP or CAC equipment before learning about the rebate that was available through Ameren Missouri. Nearly half (46%) of participants who received an advanced thermostat learned of the rebate after purchasing their equipment. For these participants, we reduced the rebate influence score by 50%.
- **Contractor Recommendation Influence**: Customers who purchased heat pumps gave the highest rating to the influence of the contractor recommendation (7.8) while those who purchased advanced thermostats gave the lowest influence rating of 7.2. Participants receiving CACs rated the contractor recommendation an influence score of 7.3 out of 10.
- **Timing:** Responses to the timing questions show that the program was responsible for accelerating the timing for advanced thermostat upgrades, but not CAC or heat pump upgrades. The resulting average timing rating was 8.1 for CACs, 7.6 for heat pump, 6.7 for advanced thermostats.
- **Efficiency:** Participants who received an CAC rated their likelihood that they would have purchased a unit with the exact same efficiency as a 6.8 out of 10 on average indicating that the program influenced customers to upgrade their equipment to a higher efficiency unit than what they were originally going to install. Participants who received heat pumps and smart thermostat rated the same likelihood question as a 7.0 and 6.7, respectively.
- **Quantity:** The program had a high influence on the scope of many CAC and advanced thermostat projects, with participants reporting that the likelihood that they would have installed the same number of units without the program averaging out to be 4 for CACs and 5 for advanced thermostats. Three participants receiving more than one heat pump rated the likelihood that they would have installed the same number of units an average of 9.
- **No Program Score Adjustment:** The results of the consistency checks indicate that the No Program Score does not take into account the influence of the contractor recommendation. To address this, the evaluation team developed an adjustment ratio that compares the influence of the rebate with the influence of the contractor recommendation. The adjustment ratio is calculated by dividing the influence of the contractor recommendation (FR4) by the influence of the rebate (FR2). If the adjustment ratio is less than 1, no adjustments were made to the No Program Score since the rebate was more influential than the contractor recommendation. If the adjustment ratio is greater than 1, the No Program Score was divided by the adjustment ratio, resulting in a weighted No Program Score.

[8] The evaluation team did not conduct NTG research for ECMs in PY2019 because this measure will no longer be offered beyond PY2019. As such, the evaluation team used PY2018 ECM NTG results.

Spillover

A total of 92 participants completed the SO questions in the participant survey and were included in the PSO analysis. The majority of these participants did not install any additional energy efficiency measures without receiving an incentive (80%)[9] or did install additional measures but were not influenced by the program (18%).

We called the 25 respondents who qualified for PSO to get more-detailed information on their SO installation such as quantities (where applicable), the baseline and efficient wattages (for lighting measures), or the equipment size (gallons and capacity). We completed follow-up calls with 16 participants. For the remaining 8, we calculated spillover using average savings values. Table 31 summarizes the results of the measure-level SO analysis.

Table 31. Summary of Measure-Level Participant Spillover

	Measure	Number of Unique Participants	Total kWh Savings
#1	Heat Pump Water Heater	5	12,905
#2	Air Purifier/Cleaner	3	2,602
#3	Pool Pump	1	1,800
#4	Dehumidifier	4	1,203
#5	Ceiling Insulation	7	694
#6	Air Sealing	7	622
#7	Refrigerator	9	504
#8	Water Heater Wrap	4	378
#9	Tier 2 Advanced Power Strip - Residential Audio Visual	1	324
#10	Clothes Washer	7	208
#11	Storm Windows	2	178
#12	Clothes Dryer	1	160
#13	Advanced Tier 1 Power Strips	4	124
#14	ENERGY STAR Dishwasher	6	108
	Total	**25**	**21,810**

[a] Represents total number of participants reporting spillover.

Dividing the estimated total SO in our sample (21,810 kWh) by total program ex post gross savings of the overall participant sample (2,556,060 kWh) yields a SO rate of 0.9%, as shown in Equation 20.

Equation 20. PY2019 HVAC Program Participant Spillover Rate

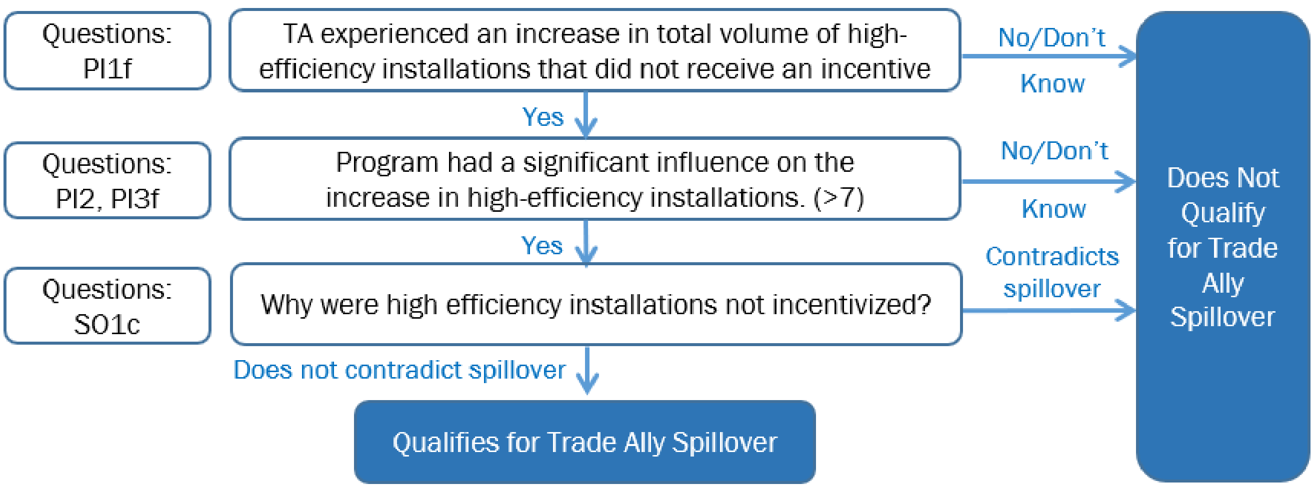
$$PSO\ \%_{Energy} = \frac{Total\ participant\ sample\ SO\ (kWh)}{Total\ participant\ sample\ savings\ (\text{kWh})} = \frac{21{,}810\ kWh}{2{,}414{,}193\ \text{kWh}} = 0.85$$

Trade Ally Spillover

[9] This percentage includes four survey respondents who reported installing additional equipment but could not name it.

Trade ally spillover (TA SO) refers to non-incented energy efficiency upgrades made by customers who were influenced by a participating trade ally influenced by Ameren Missouri's HVAC Program. The trade ally online survey asked a series of five questions to determine if any high efficiency installations completed by respondents outside of the program qualified as spillover. Figure 7 presents the methodology that we used to determine TA SO for this evaluation, including references to question numbers from the trade ally online survey (see Appendix B).

Figure 7. Trade Ally Eligibility for Spillover



Estimation of Spillover Savings for Individual Trade Allies

For each respondent who met SO qualifying conditions, we determined SO savings from the non-incented, high-efficiency installations through the following survey questions:

- The respective shares of the trade ally's total high efficiency installations during the evaluation period that did and did not receive a program incentive
- The share of high efficiency installation without an incentive that were strongly influenced by program activity in 2019
- The size of non-incented, high efficiency installations relative to those that did receive an incentive (resulting in a "Size Adjustment" factor), if applicable

Additionally, the evaluation team referenced savings information from program-tracking data associated with the HVAC Program projects for each respondent to quantify TA SO measure savings.

For the trade allies who met the qualifying conditions discussed above, we considered spillover to be equal to the savings of their non-incented, high efficiency installations, adjusted by the share that was influenced by the program. We calculated this using the following steps:

- We first determined overall (unadjusted) savings from all energy efficient installations (incented and non-incented) made by the trade ally during the evaluation period. This is estimated by dividing the savings in the program tracking database (reflecting incented savings) by the percentage of the trade ally's efficient installations that received an incentive.

- We then subtracted from that overall savings estimate the savings already tracked in the database. The resulting value represents savings from high efficiency installations that did not receive an incentive, assuming that non-incented projects have the same size as incented ones.
- We next applied the share of non-incented high efficiency installations that were strongly influenced by the program to the difference estimated in Step #2.
- In the final step, we applied a size adjustment, if needed, to reflect that non-incented projects might be of a different size (often smaller) compared to incented projects. The subsection below describes the size adjustment in more detail.

The overall equation for estimating respondent-level TA SO is:

Respondent-Level TA SO =

$$\left(\frac{\text{TA Savings from Program Database}}{\text{\% Efficient Installations That Received Incentive}} - \text{TA Savings from Program Database}\right) \times \begin{matrix}\text{\% Influenced} \\ \text{by Program}\end{matrix} \times \begin{matrix}\text{Size} \\ \text{Adjustment}\end{matrix}$$

Size Adjustment

High efficiency projects that did not receive an incentive may not be the same size as those that did receive an incentive. We therefore developed an adjustment to account for these circumstances as needed. If a respondent did not know the share of revenue from incented and non-incented high efficiency equipment, but knew the quantities of equipment, we adjusted the average size of a respondent's projects in the database up or down using responses to survey questions RS1a, RS1b, and RS1c, as shown in Table 32. Note that this adjustment is not necessary for respondents who provided valid responses to the share of revenue from incented and non-incented high efficiency equipment. Since we asked that question in terms of revenues, not the number of projects, any size differential is already be embedded in the response.

Table 32. Size Adjustment for Non-Incented, High Efficiency Installations

Non-incented, high efficiency projects are … compared to incented ones (RS1a)	How much smaller/larger? (RS1b/RS1c)	Analysis Adjustment Value
Smaller	Less than a quarter of the size	12.5%
	A quarter of the size	25%
	Half the size	50%
	Three-quarters of the size	75%
	More than three-quarters of the size	87.5%
	Unsure	*Average of all respondents where RS1a= "Smaller"*
About the Same Size	n/a	100%
Larger	Less than one-and-a-quarter times the size	112.5%
	One-and-a-quarter times the size	125%
	One-and-a-half times the size	150%
	One-and-three-quarters times the size	175%
	Twice the size	200%

Non-incented, high efficiency projects are ... compared to incented ones (RS1a)	How much smaller/larger? (RS1b/RS1c)	Analysis Adjustment Value
	More than twice the size	200.0%
	Unsure	*Average of all respondents where RS1a= "Larger"*
Unsure		*Average of all respondents*

Detailed Results

A total of 117 trade allies completed the SO section of the online survey. Nearly half of responding trade allies reported increases in the volume of high efficiency installs in Ameren Missouri's service territory that did not receive an incentive (45%). Of those reporting an increase in volume of non-incentivized high efficiency installations, two thirds of respondents (64%) attribute these increases to the HVAC Program. Trade allies most often credit the program incentive for the increases in energy-efficient installations, pointing specifically to their influence on reduced upfront costs. Trade allies also named several non-program factors that contributed to the uptick in their energy efficiency-related business practices, including increased customer interest, manufacturer rebates, tax rebates, increasing affordability of high-efficiency equipment.[10]

Over two thirds (66%) of trade allies reported having had at least one high-efficiency project that did not receive a program incentive during the evaluation period. On average, trade allies reported that 42% of their installations during the evaluation period were standard efficiency, while 44% were high efficiency and received an incentive and 14% were high efficiency and did not receive an incentive. On average, trade allies estimate that non-incented, high-efficiency installations were smaller, about 80% the size of those that received an incentive from the HVAC Program.

Overall, 4% of responding trade allies qualified for SO. Those that did not qualify experienced no increase in the volume of high efficiency installations that did not receive an incentive (55%); were not influenced by the program (33%); did not have any non-incented, high-efficiency installations (5%); or did not think that their recommendations influenced their customers' choice of non-incented, high-efficiency equipment (3%).

Trade allies who qualified for SO most often indicated that the high-efficiency installations were completed without an incentive either because equipment did not qualify for program incentives or because the program was suspended at the time that the project was completed.

We estimated SO savings for each of the trade allies who qualified for SO (five respondents, or 4%) using (1) the share of high-efficiency installations that received a program incentive; (2) the level of increase in the percentage or total volume of high-efficiency installations, and whether factors other than the program contributed to the increase; (3) the relative size of incented and non-incented projects (for trade allies who could not report the respective shares of total high-efficiency installations that did and did not receive a program incentive); and (4) the share of projects strongly influenced by the HVAC Program in 2019. The resulting trade ally spillover rate is 0.29% (Table 33).

[10] The survey collected this information to provide additional context around drivers of energy efficiency and this question was asked of a broader set of TAs than those who qualify for TASO. Of the 5 TAs that qualified for TASO, only one cited non-program factors (their company reputation and work quality). None of the TAs that qualified for TASO mentioned any of the non-program factors on the list.

Table 33. Trade Ally Spillover Savings Summary

Trade Ally	Ex Post Gross Program Savings (kWh)	Percent of High Efficiency Installations that Did Not Receive an Incentive	Share of Projects Strongly Influenced by HVAC Program in 2019	Estimated Spillover Savings (kWh)
#1	1,046	25%	100%	349
#2	2,016	23%	90%	536
#3	1,272	23%	90%	338
#4	582	11%	90%	65
#5	444	40%	70%	207
			Total	**1,496**

Home Energy Reports (HER)

The following subsections discuss the detailed methodology for estimating savings from Ameren Missouri's Home Energy Reports (HERs) Program.

Equivalency Analysis

The evaluation team performed an equivalency analysis to ensure that the treatment and control groups for each of the three waves participating in the HER Program in PY2019 were equivalent in terms of energy consumption (see Table 34). We compared average daily consumption (ADC) of electricity between treatment and control groups during their pre-participation periods to assess whether these groups were equivalent before cleaning billing data to ensure quality and completeness. Because we rely on an intent-to-treat (ITT) approach, we used the population of treatment and control customers in this equivalency analysis. We found that the two groups were equivalent for each of the waves. Wave 1 began treatment in August 2016, Wave 2 treatment began in March 2018, and Wave 3 treatment began in April 2019. We used consumption data for the year prior to program participation to calculate ADC for each wave.

Table 34. Pre-Participation Average Daily Consumption of HER Program Treatment and Control Groups by Wave

Wave	Treatment (Pre-Participation) Consumption	Control (Pre-Participation) Consumption
Wave 1	47.02	46.94
Wave 2	64.66	64.82
Wave 3	42.36	41.71

Figure 8 through Figure 10 present the pre-participation period electric consumption for both treatment and control groups for each of the waves. These figures exhibit equivalency in ADC between these groups.

Figure 8. Wave 1 Pre-Participation Period Electric Consumption, Treatment vs. Control

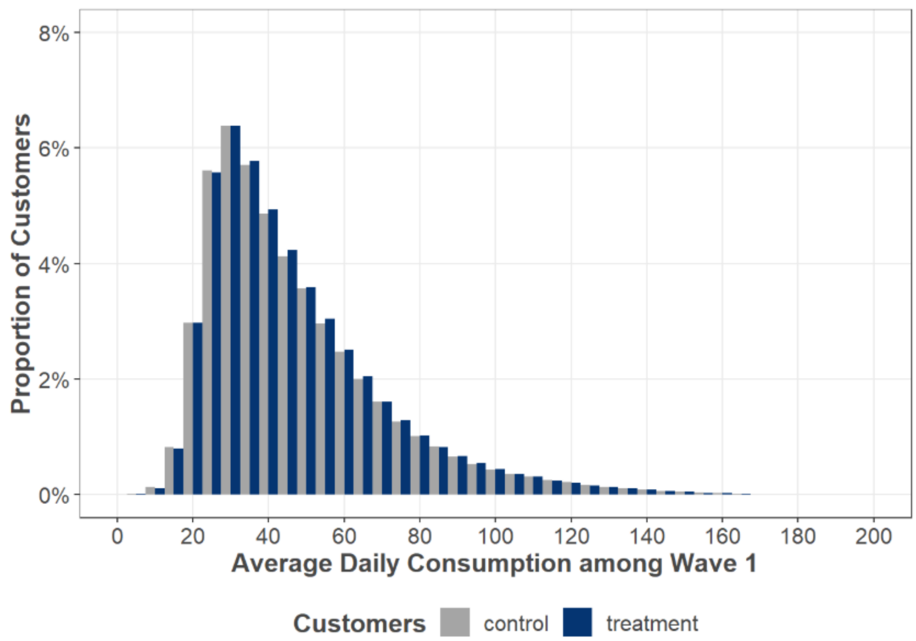


Figure 9. Wave 2 Pre-Participation Period Electric Consumption, Treatment vs. Control

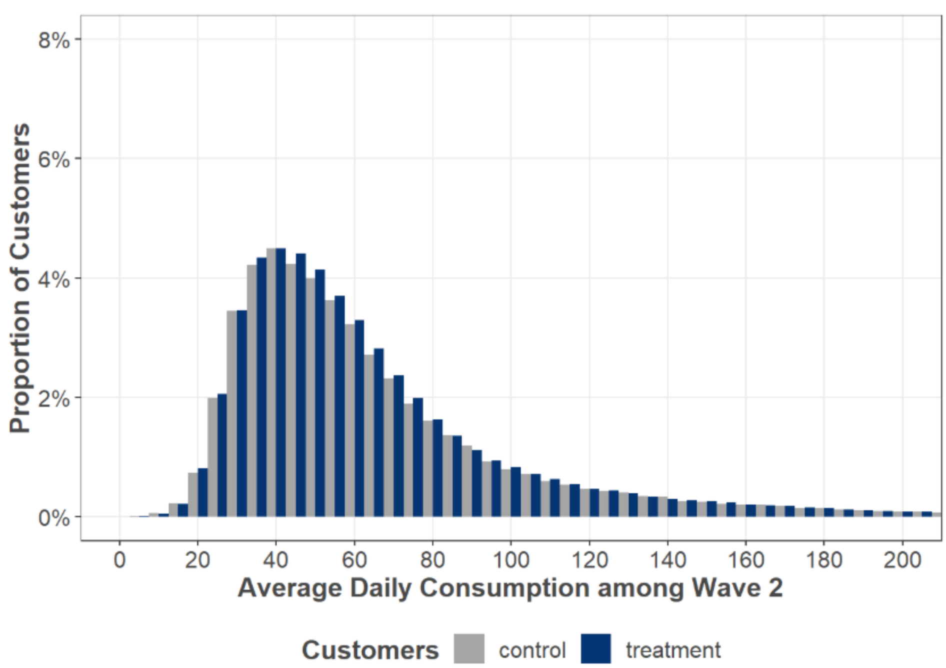
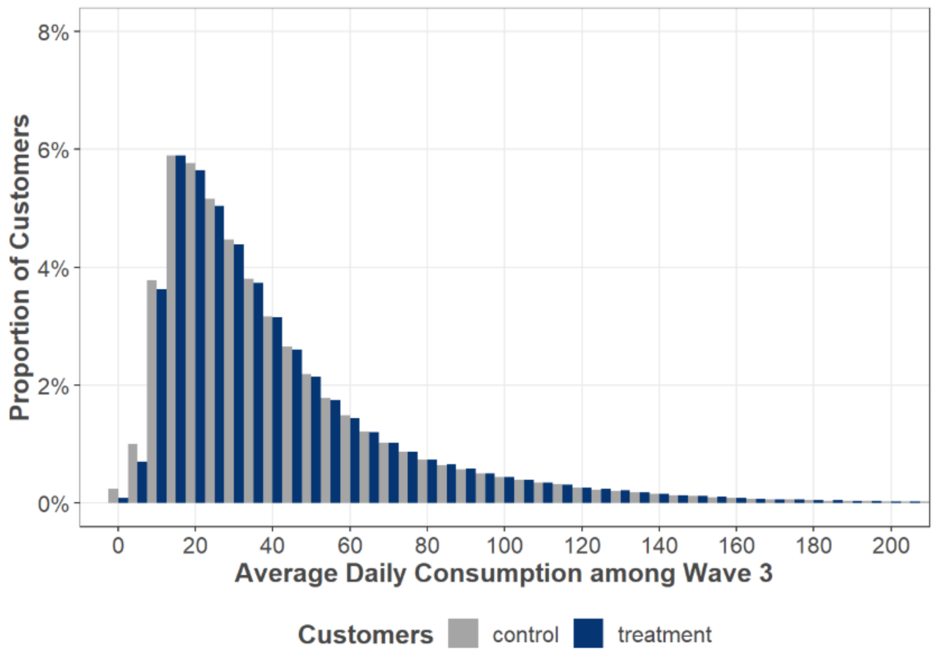


Figure 10. Wave 3 Pre-Participation Period Electric Consumption, Treatment vs. Control



Data Cleaning Results

This section shows the results of the evaluation team's data cleaning effort for the consumption analysis (see Table 35). Results include all customers that the implementation team assigned to a treatment or control group with available consumption data. We removed customers from the analysis primarily due to customers lacking sufficient pre-period consumption data (i.e., lacking at least nine months of data before the treatment period for Waves 1 and 2). For Wave 3, which only received treatment from April through December 2019, a nine-month post-period sufficiency requirement is overly stringent and would necessitate dropping a very large proportion of customers. To retain more customers for the Wave 3 analysis and have a relatively equitable expectation of sufficiency across waves, the evaluation team relaxed the standard for Wave 3 to eight months of post-period data.

In addition, there was an issue with overlapping bills within the billing dataset for the evaluation. While some of the overlapping bill issues can be attributed to receiving multiple datasets of billing data, which the evaluation team appended together to get full time period coverage, there was also a large portion of overlapping bills native to each dataset. The lack of a premise ID made it impossible to determine if some of these overlaps were due to multiple meters installed at one address, and the issues were so variable that deciding based on the data was inadvisable. For future evaluations, the evaluation team recommends that billing data for the entire time period be pulled all at once to minimize overlapping bill issues between datasets. Additionally, the team recommends including a premise ID to help identify whether overlapping bills represent multiple meters.

Table 35. Data Cleaning Results for Treatment and Control Groups by Wave

Wave	Metric	Unique Customers	
		Treatment	Control
Wave 1	Initial	76,280	25,523
	Final	74,042	25,513
	% Remaining	*97%*	*99.9%*
Wave 2	Initial	33,622	9,302
	Final	33,097	9,300
	% Remaining	*98%*	*99.9%*
Wave 3	Initial	189,868	75,929
	Final	124,227	51,040
	% Remaining	*65%*	*67%*

Modeling Program Impacts

Energy Savings

We conducted a statistical analysis to determine program impacts using monthly electric billing data for all Ameren Missouri customers who received a HER (the treatment group) and a randomly selected group of customers who did not receive a HER (the control group). The evaluation team used an ITT approach in PY2019, and we estimated savings using a lagged dependent variable (LDV) model.

Lagged Dependent Variable Model

The evaluation team used an LDV model to estimate the electric savings experienced by the HER Program's treatment group for PY2019. In this model, we only use consumption from the post-participation period to estimate impacts. We use information from the pre-participation period only to calculate pre-usage variables that we incorporated into the LDV model, but did not directly model pre-period usage. We used three levels of pre-participation period consumption for each customer: overall pre-participation period ADC, summer pre-participation period ADC, and winter pre-participation period ADC. The LDV model uses the control group in the same way as a linear fixed effects model, in that the treatment effect is corrected for control group ADC so that the coefficient of the treatment variable is the average ITT effect. We employed the following estimating equation:

Equation 21. Lagged Dependent Variable Model Estimating Equation

$$ADC_{it} = \alpha + \beta_1 Treatment_i + \beta_2 PreUsage_i + \beta_3 PreWinter_i + \beta_4 PreSummer_i + \beta_5 MonthYear_t + \beta_6 PreUsage_i \cdot MonthYear_t + \beta_7 PreWinter_i \cdot MonthYear_t + \beta_8 PreSummer_i \cdot MonthYear_t + \varepsilon_{it}$$

Where:

ADC_{it} = Average daily consumption (kWh or therms) for household *i* at time *t*

α = Model intercept

β_1 = Coefficient for the change in consumption for the treatment group

β_2 = Coefficient for the average daily usage across household *i* available pretreatment meter reads

β_3 = Coefficient for the average daily usage over the months of December through March across household *i* available pretreatment meter reads

β_4 = Coefficient for the average daily usage over the months of June through September across household *i* available pretreatment meter reads

β_5 = Vector of coefficients for month-year dummies

β_6 = Vector of coefficients for month-year dummies by average daily pretreatment usage

β_7 = Vector of coefficients for month-year dummies by average daily winter pretreatment usage

β_8 = Vector of coefficients for month-year dummies by average daily summer pretreatment usage

$Treatment_i$ = Variable to represent treatment and control groups (0 = control group, 1 = treatment group)

$PreUsage_i$ = Average daily usage for household *i* over the entire pre-participation period

$PreWinter_i$ = Average daily usage for household *i* over the pre-participation months of December through March

$PreSummer_i$ = Average daily usage for household *i* over the pre-participation months of June through September

$MonthYear_t$ = Vector of month-year dummies

ε_{it} = Error

We used the LDV model to estimate the electric savings from the PY2019 HER Program. The evaluation team presents the unadjusted per household savings for the model below. The LDV results in Table 36 replicate those presented in the Volume 1 report.

Table 36. Unadjusted Per-Household Daily Net Electric Savings – LDV Model

Wave	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (kWh per household)
Wave 1	0.56%	81
Wave 2	0.69%	128
Wave 3	0.20%	27

Billing Analysis Model Coefficients

Table 37 provides the billing analysis model coefficients for the LDV model.

Table 37. LDV Model Billing Analysis Model Coefficients

Variables	Coefficient [a]	Standard Error
Wave 1		
(Intercept)	6.83	0.18

Variables	Coefficient [a]	Standard Error
treat	-0.27	0.03
pre_adc	-0.68	0.02
pre_adc_summ	0.16	0.01
pre_adc_win	1.41	0.01
my022019	0.40	0.25
my032019	0.91	0.25
my042019	-1.65	0.25
my052019	-3.46	0.25
my062019	-1.70	0.25
my072019	3.42	0.25
my082019	1.55	0.25
my092019	1.28	0.25
my102019	-1.27	0.25
my112019	-0.17	0.25
my122019	-0.02	0.26
pre_adc:my022019	-0.07	0.02
pre_adc:my032019	1.07	0.02
pre_adc:my042019	2.10	0.02
pre_adc:my052019	1.82	0.02
pre_adc:my062019	1.31	0.02
pre_adc:my072019	0.75	0.02
pre_adc:my082019	0.98	0.02
pre_adc:my092019	1.28	0.02
pre_adc:my102019	1.68	0.02
pre_adc:my112019	0.89	0.02
pre_adc:my122019	0.61	0.02
pre_adc_summ:my022019	-0.01	0.01
pre_adc_summ:my032019	-0.37	0.01
pre_adc_summ:my042019	-0.58	0.01
pre_adc_summ:my052019	-0.16	0.01
pre_adc_summ:my062019	0.26	0.01
pre_adc_summ:my072019	0.63	0.01
pre_adc_summ:my082019	0.47	0.01
pre_adc_summ:my092019	0.25	0.01
pre_adc_summ:my102019	-0.35	0.01
pre_adc_summ:my112019	-0.27	0.01
pre_adc_summ:my122019	-0.15	0.01
pre_adc_win:my022019	0.08	0.01

Variables	Coefficient [a]	Standard Error
pre_adc_win:my032019	-0.80	0.01
pre_adc_win:my042019	-1.66	0.01
pre_adc_win:my052019	-1.74	0.01
pre_adc_win:my062019	-1.64	0.01
pre_adc_win:my072019	-1.45	0.01
pre_adc_win:my082019	-1.52	0.01
pre_adc_win:my092019	-1.63	0.01
pre_adc_win:my102019	-1.50	0.01
pre_adc_win:my112019	-0.73	0.01
pre_adc_win:my122019	-0.51	0.01
Wave 2		
(Intercept)	3.45	0.27
treat	-0.42	0.06
pre_adc	0.22	0.02
pre_adc_summ	-0.15	0.01
pre_adc_win	0.94	0.01
my022019	0.13	0.38
my032019	1.62	0.37
my042019	-0.79	0.37
my052019	-3.74	0.37
my062019	-1.51	0.38
my072019	3.73	0.37
my082019	1.84	0.38
my092019	1.39	0.38
my102019	-0.06	0.38
my112019	0.80	0.38
my122019	1.27	0.39
pre_adc:my022019	-0.05	0.03
pre_adc:my032019	0.90	0.03
pre_adc:my042019	1.52	0.03
pre_adc:my052019	1.13	0.03
pre_adc:my062019	0.38	0.03
pre_adc:my072019	-0.11	0.03
pre_adc:my082019	0.09	0.03
pre_adc:my092019	0.41	0.03
pre_adc:my102019	0.88	0.03
pre_adc:my112019	0.71	0.03
pre_adc:my122019	0.55	0.03

Variables	Coefficient [a]	Standard Error
pre_adc_summ:my022019	-0.01	0.02
pre_adc_summ:my032019	-0.35	0.01
pre_adc_summ:my042019	-0.39	0.01
pre_adc_summ:my052019	0.10	0.01
pre_adc_summ:my062019	0.66	0.02
pre_adc_summ:my072019	1.01	0.01
pre_adc_summ:my082019	0.86	0.01
pre_adc_summ:my092019	0.61	0.02
pre_adc_summ:my102019	-0.05	0.02
pre_adc_summ:my112019	-0.24	0.02
pre_adc_summ:my122019	-0.16	0.02
pre_adc_win:my022019	0.05	0.01
pre_adc_win:my032019	-0.68	0.01
pre_adc_win:my042019	-1.34	0.01
pre_adc_win:my052019	-1.36	0.01
pre_adc_win:my062019	-1.15	0.01
pre_adc_win:my072019	-0.98	0.01
pre_adc_win:my082019	-1.05	0.01
pre_adc_win:my092019	-1.16	0.01
pre_adc_win:my102019	-1.09	0.01
pre_adc_win:my112019	-0.61	0.01
pre_adc_win:my122019	-0.47	0.01
Wave 3		
(Intercept)	0.17	0.08
treat	-0.07	0.02
pre_adc	1.66	0.01
pre_adc_summ	-0.43	0.01
pre_adc_win	-0.49	0.01
my052019	-0.78	0.10
my062019	0.00	0.10
my072019	2.90	0.10
my082019	1.89	0.10
my092019	1.73	0.10
my102019	0.80	0.10
my112019	0.92	0.10
my122019	0.73	0.10
pre_adc:my052019	-0.08	0.02
pre_adc:my062019	-0.68	0.02

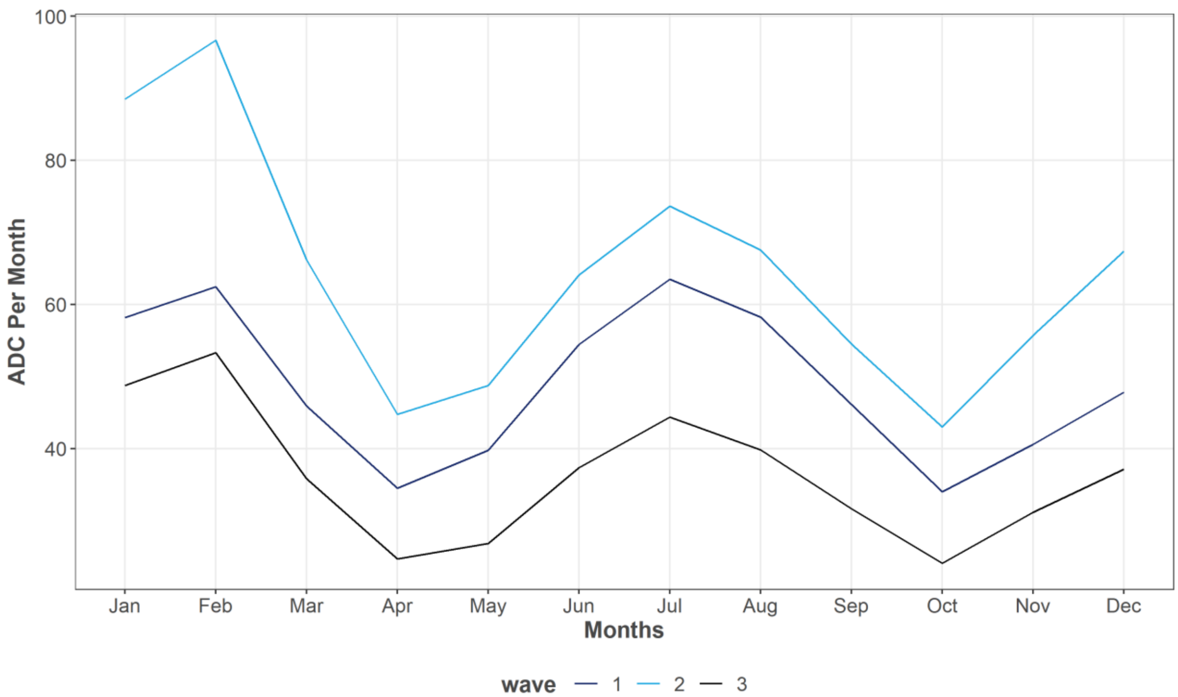
Variables	Coefficient [a]	Standard Error
pre_adc:my072019	-1.15	0.02
pre_adc:my082019	-0.95	0.02
pre_adc:my092019	-0.69	0.02
pre_adc:my102019	-0.11	0.02
pre_adc:my112019	-0.53	0.02
pre_adc:my122019	-0.84	0.02
pre_adc_summ:my052019	0.28	0.01
pre_adc_summ:my062019	0.76	0.01
pre_adc_summ:my072019	1.13	0.01
pre_adc_summ:my082019	0.97	0.01
pre_adc_summ:my092019	0.78	0.01
pre_adc_summ:my102019	0.09	0.01
pre_adc_summ:my112019	0.03	0.01
pre_adc_summ:my122019	0.16	0.01
pre_adc_win:my052019	-0.08	0.01
pre_adc_win:my062019	0.10	0.01
pre_adc_win:my072019	0.29	0.01
pre_adc_win:my082019	0.21	0.01
pre_adc_win:my092019	0.11	0.01
pre_adc_win:my102019	0.08	0.01
pre_adc_win:my112019	0.70	0.01
pre_adc_win:my122019	0.91	0.01

[a] All coefficients are statistically significant at the 90% confidence level.

Pre-Period Monthly ADC by Wave

In an effort to understand the drivers of energy savings by wave, the evaluation team plotted the pre-period ADC for the treatment customers in each wave to examine the differences in baseline consumption. Figure 11 shows the pre-period monthly average daily consumption (ADC) for each wave in 2015, a common year of pre-period for all three waves. Wave 3, the most recent wave, has lower ADC values for every month. This is likely due to Wave 3's higher composition of customers living in apartments and low-income customers, discussed further below.

Figure 11. Annual Pre-Period ADC per Month by Wave (for 2015)



We also examined the customer accounts included in the tracking data. As shown in Table 38, while 95% of Waves 1 and 2 are comprised of single family customers, only 63% of Wave 3 are single family customers. Wave 3 has a much higher percentage of customers in apartments, mobile homes, and multifamily units, as well as more commercial buildings and single metered multi-tenant homes. Table 38 and Table 39 show that Wave 3 also has a higher incidence of low-income customers, at 5% low-income, while the other two waves only have 1-2% low-income.

Table 38. Housing Type by Wave

Housing Type	Wave 1	Wave 1 %	Wave 2	Wave 2 %	Wave 3	Wave 3 %
Single Family	96,402	95%	40,609	95%	166,530	63%
Apartment	1,640	2%	562	1%	62,076	23%
NA	1,514	1%	618	1%	18,351	7%
Mobile Homes	2,021	2%	1,032	2%	13,575	5%
Multi Dwelling	71	0%	28	0%	4,163	2%
Commercial Building	50	0%	30	0%	631	0%
Single Metered Multi-Tenant	41	0%	18	0%	200	0%
Other	13	0%	5	0%	116	0%
Temporary Services	49	0%	21	0%	113	0%
Condominium					79	0%
Modular Home					10	0%
Office	1	0%	1	0%	8	0%
Recreation Parks					7	0%

Housing Type	Wave 1	Wave 1 %	Wave 2	Wave 2 %	Wave 3	Wave 3 %
Unmetered Street Lights	2	0%	1	0%	5	0%
Church					4	0%
Farms 2nd Meter					5	0%
School	1	0%			2	0%
Metered Street Lighting			1	0%	1	0%
Boarding House					1	0%
Retail					1	0%
Common Use Facility					1	0%
Warehouse					1	0%
Unmetered CATV Supply			1	0%		
Unmetered					2	0%
Total	**101,805**	-	**42,927**	-	**265,882**	-

Table 39. Low Income Customers by Wave

Low Income	Wave 1	Wave 1 %	Wave 2	Wave 2 %	Wave 3	Wave 3 %
Yes	1,269	1%	825	2%	13,546	5%
No	99,022	97%	41,484	97%	233,985	88%
Unknown	1,514	1%	618	1%	18,351	7%
Total	**101,805**	-	**42,927**	-	**265,882**	-

Demand Reductions

We calculated demand impacts based on the Missouri TRM, which applies a peak adjustment factor to modeled energy savings results. The factor value used to arrive at PY2019 HER demand savings is 0.000466081 kW.

Participation Uplift and Joint Savings Analysis

We also determined whether the Ameren Missouri HER Program treatment generated participation uplift in other PY2019 (i.e., an increase in participation in other energy efficiency programs in PY2019 as a result of the Ameren Missouri HER Program). To complete this analysis, we calculated whether more treatment than control group members participated in other residential energy efficiency initiatives after receiving HERs compared to participation before receiving HERs. We cross-referenced the HER Program database—both treatment and control groups — with the databases of other residential energy efficiency programs offered by Ameren Missouri in PY2019. We include the following residential programs in our analysis for 2019:

- Appliance Recycling
- Efficient Products
- Peak Time Savings
- Single Family Low Income
- Multifamily Low Income

- Multifamily Market Rate
- Heating, Ventilation, and Air Conditioning
- Online Retail Lighting
- Upstream Lighting

Through this analysis, we calculated the number of customers who participated in both the HER Program and other energy efficiency programs in PY2019 for each wave. To ensure the participation uplift is attributable solely to the HER Program, we calculated participation uplift using a post-only difference (POD) estimator. We identified the total number of treatment and control group customers who participated in an Ameren Missouri energy efficiency program in PY2019. Any positive difference between the treatment and control population that was statistically significant was the net participation due to the HER Program. We ignored any negative POD.

To arrive at the participation uplift rate, the evaluation team calculated the POD estimator for each wave for each program using Equation 22:

Equation 22. POD Estimator

POD = Current PY Treatment Group Participation Rate in EE Program –

Current PY Treatment Group Participation Rate in EE Program

We multiplied the positive and significant POD statistic by the total number of treatment customers in the relevant wave to obtain the participation uplift value. The uplift value is the total number of participants that, according to this analysis, participated in other energy efficiency programs due to HER treatment. There is an uplift value for each energy efficiency program and wave where at least some participation in the program occurred. Equation 23 was used to calculate participation uplift.

Equation 23. Participation Uplift Rate

Participation Uplift = (POD for Wave) x (Total Number of HER Treatment Participants in Wave)

Finally, we calculated the savings adjustment value. We multiplied the participation uplift by the median energy efficiency program savings value of the treatment group participants in the associated program and wave of to obtain the savings adjustment. The savings adjustment is the value used to adjust the current HER Program energy savings downward to control for the double-counting of savings. There is a savings adjustment value for each EE program and wave where at least some participation in the program occurred. The calculation is as follows:

Equation 24. Savings Adjustment

Savings Adjustment = (Participation Uplift for Wave) x (Median EE Program Savings of Treatment Group of Wave)

One notable exception is the Upstream Lighting Program. Because the is no systematic way to track Ameren Missouri customer account numbers associated with purchases of upstream lighting, the evaluation team used the survey to gather information about whether treatment and control customers purchased bulbs at locations where rebated LEDs were sold. An analysis of the data we collected showed no difference in the number of treatment and control customers purchasing upstream LEDs. The team therefore determined that participation uplift due to the HER Program was zero for this program.

We observed a statistically significant uplift effect only for participation in the HVAC Program from Wave 2. To calculate the savings deduction required due to the higher participation of treatment customers in the HVAC Program relative to control customers, the evaluation team multiplied the annual ex post median participant savings (2,974.98 kWh) for the HVAC Program in PY2019 by the participation uplift rate (157.79). The savings adjustment is multiplied by 10/12 so that the adjustment for Wave 2 matches the months of claimable savings for Wave 2 this year.

Energy Efficient Products (REP)

Gross Impact Methodology

Heat Pump Water Heater Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential Efficient Products Program heat pump water heater measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 25.

Equation 25. Heat Pump Water Heater Energy and Demand Savings Equations

$$kWh = \frac{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{EE}}\right) \times GPD \times Household \times 365.25 \times \gamma Water \times (T_{Out} - T_{In}) \times 1.0}{3{,}412} + kWh_{Cool} - kWh_{Heat}$$

$$kWh_{Cool} = \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) \times GPD \times Household \times 365.25 \times \gamma Water \times (T_{Out} - T_{In}) \times 1.0\right) \times LF \times WHF_C \times LM}{COP_{Cool} \times 3{,}412}\right] \times \%Cool$$

$$kWh_{Heat} = kWh_{Electric\ Resistance\ Heating} + kWh_{Heat\ Pump\ Heating}$$[11]

$$kWh_{ER\ Heating} = \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) \times GPD \times Household \times 365.25 \times \gamma Water \times (T_{Out} - T_{In}) \times 1.0\right) \times LF \times WHF_H}{COP_{Electric\ Resistance} * 3{,}412}\right] \times \%ElectricHeat_{ER}$$

$$kWh_{HP\ Heating} = \left[\frac{\left(\left(1 - \frac{1}{EF_{EE}}\right) \times GPD \times Household \times 365.25 \times \gamma Water \times (T_{Out} - T_{In}) \times 1.0\right) \times LF \times WHF_H}{COP_{Heat\ Pump} * 3{,}412}\right] \times \%ElectricHeat_{HP}$$

Where:

[11] kWh_{Haet} was calculated for an unknown electric heating system type in accordance with the November 2019 Appendix F, which calculates a weighted average kWh_{Heat} value based on the percentage of homes with electric resistance heating and heat pump heating. Percentages deemed in Appendix F are based on PY2018 Efficient Products Program tracking data.

EFBase = Energy factor of baseline equipment = 0.945

EFEE = Energy factor of efficient equipment = 3.44

GPD = Gallons per day = 17.6

Household = Average number of people per household = 2.65

365.25 = Days per year

γWater = Specific weight of water in pounds per gallon = 8.33

TOut = Tank temperature = 125ºF

TIn = Incoming water temperature from well or municipal system = 57.898ºF

1.0 = Heat capacity of water in Btu/lb-ºF

3,412 = Conversion factor from Btu to kWh

LF = Location factor = 0.81

WHFC = Portion of reduced waste heat that results in cooling savings = 53%

COPCool = COP of central air conditioner = 2.8

LM = Latent multiplier to account for latent cooling demand = 1.33

%Cool = Percentage of homes with central cooling = 100%

WHFH = Portion of reduced waste heat that results in increased heating load = 43%

COPElectric Resistance = COP of electric resistance heating system = 1.0

COPHeat Pump = COP of heat pump heating system = 1.92

%ElectricHeatElectric Resistance = Percentage of homes with electric resistance heating = 22.3%

%ElectricHeatHeat Pump = Percentage of homes with heat pump heating = 26.9%

CF = Coincidence factor = 0.0000887318

Advanced Thermostats Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential Efficient Products Program advanced thermostat measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 26.

Equation 26. Advanced Thermostat Energy and Demand Savings Equation

$$kWh = kWh_{Heating} + kWh_{Cooling}$$

$$kWh_{Heating} = \%ElectricHeat \times HeatingConsumption_{Electric} \times HF \times HeatingReduction \times ISR + (\Delta Therms \times Fe \times 29.3)$$

$$kWh_{Cooling} = \%AC \times \frac{\left(EFLH_{Cool} \times CapacityCool \times \frac{1}{SEER}\right)}{1000} \times CoolingReduction \times ISR$$

$$\Delta Therms = \%FossilHeat \times HeatingConsumption_{Gas} \times HF \times HeatingReduction \times ISR$$

$$kW = kWh_{Cooling} \times CF$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric = 100% if electric heating system; 0% if natural gas heating; 16% if unknown

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes, in kWh

Table 40. $HeatingConsumption_{Electric}$ for Advanced Thermostat Measures

Heating Equipment	$HeatingConsumption_{Electric}$
Electric Heat Pump	8,355
Electric Resistance	14,202
Natural Gas System	0
Unknown	11,456

HF = Household factor, to adjust heating consumption for non-single-family households = 100% if single-family, 65% if multi-family

HeatingReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat = 6.67%

ISR = In-service rate = 98.8%

ΔTherms = Therm savings if natural gas heating system, calculated using equation defined above

Fe = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

29.3 = Conversion factor of kWh per therm

%AC = Fraction of customers with thermostat-controlled air conditioning = 100%

EFLHCool = Equivalent full load hours of air conditioning = 869

CapacityCool = Capacity of air cooling system in Btu/hr = 36,552

SEER = Seasonal Energy Efficiency Ratio rating of the cooling equipment in kBtu/kWh = 13.55

1/1000 = Conversion factor of kBtu per Btu

CoolingReduction = Assumed percentage reduction in total household cooling energy consumption due to advanced thermostat = 8.0%

%FossilHeat = percentage of heating savings assumed to be natural gas = 0% if electric heating system; 100% if natural gas heating; 84% if unknown

HeatingConsumptionGas = Estimate of annual household heating consumption for gas-heated single-family homes, in therms = 682

CF = Coincidence factor = 0.0009474181

Pool Pump Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential Efficient Products Program pool pump measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 27.

Equation 27. Pool Pump Energy and Demand Savings Equations

$$kWh = Days_{Oper} \times \left[\left(\frac{kWh_{ss}}{Day}\right) - \left(\frac{kWh_{ds}}{Day}\right)\right] \times ISR$$

$$\left(\frac{kWh_{ss}}{Day}\right) = \frac{RT_{ss} \times GPM_{ss} \times 60}{EF_{ss} \times 1000}$$

$$\left(\frac{kWh_{ds}}{Day}\right) = \left(\frac{kWh_{hs}}{Day}\right) + \left(\frac{kWh_{ls}}{Day}\right)$$

$$\left(\frac{kWh_{hs}}{Day}\right) = \frac{RT_{hs} \times GPM_{hs} \times 60}{EF_{hs} \times 1000}$$

$$\left(\frac{kWh_{ls}}{Day}\right) = \frac{RT_{ls} \times GPM_{ls} \times 60}{EF_{ls} \times 1000}$$

$$kW = kWh \times CF$$

Where:

DaysOper = Days per year of operation = 121.6

RTss = Runtime in hours per day using single-speed (ss) pump = 11.4

RThs = Runtime in hours per day in high speed (hs) using a dual-speed (ds) pump = 2.0

RTls = Runtime in hours per day in low speed (ls) using a dual-speed (ds) pump = 9.8 for multi-speed pump; 10.0 for variable-speed pump

GPMss = Gallons per minute using single-speed (ss) pump = 64.4

GPMhs = Gallons per minute in high speed (hs) using a dual-speed (ds) pump = 56.0 for multi-speed pump; 50.0 for variable-speed pump

GPMls = Gallons per minute in low speed (ls) using a dual-speed (ds) pump =31.0 for multi-speed pump; 30.6 for variable-speed pump

EFss = Energy factor using single-speed (ss) pump, in gallons per Watt-hour = 2.1

EFhs = Energy factor in high speed (hs) using a dual-speed (ds) pump, in gallons per Watt-hour = 2.4 for multi-speed pump; 3.8 for variable-speed pump

EFls = Energy factor in low speed (ls) using a dual-speed (ds) pump, in gallons per Watt-hour = 5.4 for multi-speed pump; 7.3 for variable-speed pump

ISR = In-service rate = 100%

CF = Coincidence factor = 0.0002354459

Tier 2 Power Strips Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Residential Efficient Products Program tier 2 power strip measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The team calculated electric energy and demand savings using the algorithms outlined in Equation 28.

Equation 28. Tier 2 Power Strips Energy and Demand Savings Equations

$$kWh = (ERP \times BaselineEnergy_{AV}) \times ISR$$

$$kW = kWh \times CF$$

Where:

ERP = Energy reduction percentage of qualifying tier 2 power strip = 37.5%, average ERP of all product classes given in TRM

BaselineEnergyAV = Baseline audio visual (AV) energy consumption, in kWh = 432

ISR = In-service rate = 93.8%

CF = Coincidence factor = 0.0001148238

Net Impact Methodology

Participant Free-Ridership

The FR assessment consists of two components:

- A Program Influence component, based on the participant's perception of the program's influence on the decision to carry out the energy-efficient project; and
- A No-Program component, based on the participant's intention to carry out the energy-efficient project without program funds.

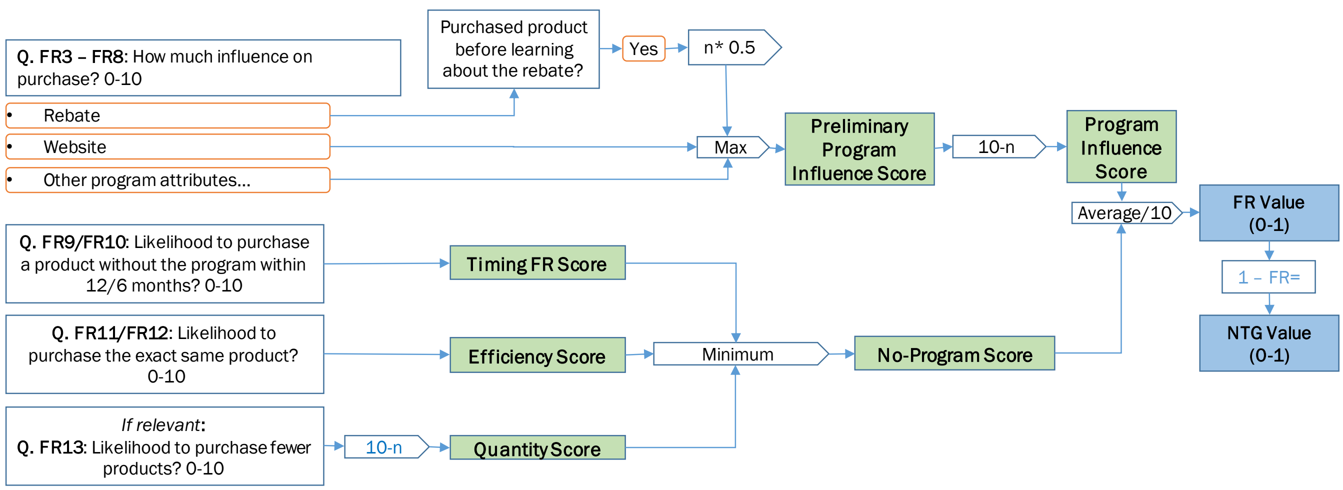
When scored, each component assesses the likelihood of FR on a scale of 0 to 10, with the two scores averaged and for a combined total FR score. FR is the mean of the two components:

$$Free\ Ridership\ (FR) = \ Mean(Program\ Influence, No\ Program\ Score)$$

As different and opposing biases potentially affect the two main components, the No-Program component typically indicates higher FR than the Program Influence component. Therefore, combining these decreases the biases. Figure 6 presents a diagram of the FR algorithm we will use, including references to question numbers.

For participants purchasing advanced thermostats and power strips through the Online Store, we asked participants to rate the influence of the rebate discount and the influence of the information on the Ameren Missouri Online Store. For participants purchasing pool pumps and heat pump water heaters through the Brick-and-Mortar method, we asked participants to rate the influence of the rebate discount, the influence of in-store materials, and the influence of contractor recommendations. As part of the FR survey module, we also referenced retail pricing to ground participant responses.

Figure 12. Efficient Products Program Free Ridership Algorithm



Calculation of the Program Influence Score

Program influence is assessed by asking respondents, on a scale from 0 (not at all influential) to 10 (extremely influential), how important they found various program elements to be on their decision to purchase the high efficiency measure. The number of elements included will vary, depending on the participation pathway (e.g., Ameren Missouri Online Store vs. Retail Store/Contractor). Elements include potential influences on customer decision making: information; discounts or rebates; interaction with retail store employees and/or contractors.

In addition to asking about specific program influences, respondents are asked whether they planned to purchase a high-efficiency version of the product before learning of the Online Store or rebate program. Respondent's rating of the discount's/rebate's influence is adjusted by 0.5 for those answering the question "yes."

The Preliminary Program Influence Score equals the maximum influence rating for any program element rather than, for example, the mean influence rating. This is based on the rationale that if any given program element had a great influence on the respondent's decision, then the program itself had a great influence, even if other elements had less influence. An inverse relationship occurs between high program influence and FR: the greater the program influence, the lower the FR. The Program Influence (PI) Score = 10 - Preliminary Program Influence Score.

Calculation of the No-Program Score

The No-Program (NP) Score is based on three measures of the likelihood of a participant purchasing the exact same item(s) at the same time in the absence of the program. Each of these likelihood measures are assessed on a 0-10 scale in which 0 means "not at all likely" and 10 means "very likely."

First, the participant is asked about their likelihood of purchasing an item of *any efficiency* within 12 or 6 months (12 months for a single or big-ticket item such as a Pool Pump or Heat Pump Water Heater and 6 months for less expensive items such as a Smart Thermostat or Power Strip) for the Timing (T) Score. Participants who were influenced by the program to replace still-functioning equipment will likely give a low score to this question, while participants who needed to replace burned out equipment will give a high score. This measure enables the analysis to use a single algorithm for both early replacement and replace-on-burnout scenarios.

Next, the respondent is asked to gauge their likelihood of purchasing the *exact same item* (e.g., make, model, efficiency) had the program not existed. This measure forms the Efficiency (E) Score. A respondent stating the likelihood of purchasing the same exact item as a 5 on a scale of 0 to 10 is assigned an Efficiency Score of 5. Additionally, if multiple quantities of an item are purchased, the respondent is asked about the likelihood of purchasing fewer energy-efficient items. The response to this question is subtracted from 10 to compute the Quantity (Q) Score.

The No-Program Score is the minimum of the Timing, Efficiency, and (if applicable) Quantity Scores. Finally, the No-Program Score is averaged with the Program Influence Score to calculate the Final FR Value.

$$No\ Program\ Score\ (NP) = \ Min(T, E, Q)$$

Consistency Checks

To address the possibility of conflicting responses (i.e., low intention score and high influence score), the survey included a consistency check that asked participants an open-ended question to address the program's influence. For example:

- How did the Ameren Missouri Online Store (Ameren Missouri Program) influence your decision to purchase the <insert measure>?

We assessed the response to this open-ended question and its consistency with the other questions, and, if warranted—based on clear additional information—adjusted the score based on expert judgement.

Results

The evaluation team surveyed 1,063 total REP Program participants to develop individual FR and PSO scores. Table 41 presents the results of our NTG analysis.

Table 41. PY2019 REP Program NTGR

Measure/End-Use	Free-Ridership (FR)	Participant Spillover (PSO)	NTGR (1-FR+PSO)
Advanced Thermostats	29.3%	2.8%	73.5%

Measure/End-Use	Free-Ridership (FR)	Participant Spillover (PSO)	NTGR (1-FR+PSO)
Pool Pumps	35.6%	2.8%	67.2%
Heat Pump Water Heaters	40.4%	2.8%	62.4%
Tier 2 Power Strips	16.6%	2.8%	86.2%
Overall Program	**31.8%**	**2.8%**	**71.0%**

Program free ridership varies by measure. Advanced thermostats, which contributed the majority of gross savings to the program (64% of ex post gross), had the second lowest free ridership rate (29.3%). Pool pumps, which contributed the bulk of the remaining gross savings (31% of ex post gross) had a free ridership rate of 40.4%.

Based on results from the participant survey, we identified 31 respondents who had installed a combined 74 measures that qualified for PSO. Our engineering analysis of SO measures for these participants yielded total spillover savings of 19,997 kWh (see Table 42).

Table 42. PY2019 REP Program Participant Spillover and Savings

Measure	Qty	Savings
Ceiling Insulation	9	1,084
Advanced Thermostat	8	1,903
Refrigerator	7	377
Low Flow Faucet Aerator	2	0
Low Flow Showerhead	5	0
Storm Windows	2	154
Air Sealing	8	826
Advanced Tier 1 Power Strips	4	124
Clothes Washer	7	208
Water Heater Wrap	3	284
Heat Pump Water Heater	4	10,324
Cooling Equipment	2	465
Heating Equipment	3	1,245
Pool Pump	1	1,800
Dehumidifier	1	301
Air Purifier/Cleaner	1	867
ENERGY STAR Dishwasher	2	36
Other	5	0
Total	**74**	**19,997**

We divided our estimate of PSO savings from our survey respondents (19,997 kWh) by total program ex post gross savings of all surveyed participants (722,759 kWh), which yields a SO rate of 2.8%, as shown in Equation 59.

Equation 29. PY2019 Efficient Products Program Participant Spillover Rate

$$PSO\ \%_{Energy} = \frac{Total\ participant\ sample\ SO\ (kWh)}{Total\ participant\ sample\ savings\ (\mathrm{k}Wh)} = \frac{19{,}997\ kWh}{722{,}759\ \mathrm{k}Wh} = 2.8\%$$

Energy Efficiency Kits (EEK)

Gross Impact Methodology

Energy Efficient Kit Faucet Aerator Saving Assumption

To calculate verified gross energy and demand savings for PY2019 EEK Program the faucet aerator measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 30. EEK Faucet Aerator electric savings equation.

$$\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * 365.25 * DF / FPH) * EPG\_electric * ISR$$

Equation 31. EEK Faucet Aerator demand savings equation.

$$\Delta kW = \Delta kWh * CF$$

Table 43. Faucet Aerator Input Values

Input	Bathroom	Kitchen	Source
%ElectricDHW	0.42	0.42	PY2019 Survey
GPM_base	2.2	2.2	Deemed savings table
L_base	1.6	4.5	Appendix I
GPM_low	1.5	1.5	Deemed savings table
L_low	1.6	4.5	Appendix I
Household	4.285	4.285	PY2019 Survey
DF	0.9	0.75	Appendix I
FPH	2.2839	1.1875	Appendix I
EPG	0.061532	0.0789712	Appendix I
ISR	0.48	0.4	PY2019 Survey
Coincidence Factor (CF)	0.0000887318	0.00008873118	Appendix I
Leakage	0.72	0.72	PY2019 Survey

%ElectricDHW = Proportion of water heating supplied by electric resistance heating.

GPM_Base = Average flow rate, in gallons per minute, of the baseline faucet "as-used.".

L_base = Average baseline length of daily faucet use per capita in minutes.

GPM_Low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used".

L-Low = Average retrofit daily length faucet use per capita for faucet of interest in minutes.

Household = Average number of people per household

DF = Drain Factor

FPH = Faucets per Home

EPG = Energy per gallon of water used by faucet supplied by electric water heater

ISR = In Service rate of faucet aerators

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Coincidence Factor = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

Energy Efficient Kit Low Flow Shower Head Saving Assumption

To calculate verified gross energy and demand savings for PY2019 EEK program the low flow shower head measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 32. Low Flow Shower Head Energy Savings.

$$\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * SPCD * 365.25 / SPH) * EPG\_electric * ISR$$

Equation 33. Low Flow Shower Head Demand Savings.

$$\Delta kW = \Delta kWh * CF$$

ΔkWh = as calculated above

Table 44. Low Flow Shower Head Input Values.

Input	Value	Source
%ElectricDHW	0.42	PY2019 Survey
GPM_base	2.35	Appendix I
L_base	7.8	Appendix I
GPM_low	1.5	Appendix I

Input	Value	Source
L_low	7.8	Appendix I
Household	4.285	PY2019 Survey
SPCD	0.832	PY2019 Survey
SPH	2.14	PY2019 Survey
EPG	0.1088	Appendix I
ISR	0.54	PY2019 Survey
Coincidence Factor (CF)	0.000088732	Appendix I
Leakage	0.72	PY2019 Survey

%ElectricDHW = Proportion of water heating supplied by electric resistance heating.

GPM_Base = Average flow rate in gallons per minute of the baseline showerhead.

L_base = Shower length in minutes with baseline showerhead

GPM_Low = Average flow rate in gallons per minute of the low-flow showerhead.

L-Low = Shower length in minutes with low-flow showerhead

Household = Average number of people per household

SPCD = Shower per capita per day

SPH = Showerheads per household so that per showerhead savings fractions can be determined

EPG = Energy per gallon of hot water supplied by electric

ISR = In service rate of showerhead

Coincidence Factor = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Energy Efficient Kit LED – 10W (Halogen Baseline) Savings Assumption

To calculate verified gross energy and demand savings for PY2019 EEK program the 10W LED measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 34. LED Lighting Energy Savings.

$$\Delta kWh_{RES} = (Watt_{Base} - Watt_{EE}) * \%RES * ISR * (1 - LKG) * (Hours_{RES} * WHF_{RES}) / 1{,}000$$

Equation 35. LED Lighting Demand Savings

$$\Delta kW = \Delta kWh * CF$$

Table 45. LED Lighting Input Values.

Input	Value	Source
Watts Base	43	Appendix I
Watts EE	9	Appendix I
ISR (cumulative)	0.920	PY2019 Survey
Hours Res	996.45	Appendix I
WHF	0.99	Appendix I
Coincidence Factor (CF)	0.000149253	Appendix I
%Res	1	Appendix I
Leakage	0.72	PY2019 Survey

Watts Base = Wattage of the baseline bulb that was installed prior to the efficient bulb

Watts EE = Wattage of efficient light bulb

% Res = Percentage of light bulbs handed out to residential customers

ISR = In service rate, percentage of units rebated that are actually in service based on estimated future installation rate trajectory

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Hours Res = Average hours of use per year.

WHF = Waste heat factor for energy to account for electric heating increase from the reduction of waste heat from efficient lighting.

Coincidence Factor = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

LED In-Service Rate

We estimated the ISRs for LEDs offered through the EEK Program using the installation trajectory approach recommended by the UMP.[12] Similar to our approach to estimating ISRs for the Residential Lighting Program, we developed both a first year ISR and cumulative ISR reflecting future installations over a six year period (see Residential Lighting Gross Impact Methodology Section). The first year and cumulative ISRs for LEDs provided through the EEKs are presented in Table 46 below.

Table 46. First Year and Future Trajectory ISR for EEK LEDs

First Year ISR	Cumulative ISR
0.772	0.920

Energy Efficient Kit Dirty Filter Alarm Savings Assumption

To calculate verified gross energy and demand savings for PY2019 EEK program the Dirty Filter Alarm measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 36. Dirty Filter Alarm Energy Savings

$$kWh\ Heating\ Savings = kW_{motor} * FLH_{heat} * EI * ISR$$

$$kWh\ Cooling\ Savings = kW_{motor} * FLH_{cool} * EI * ISR$$

Equation 37. Dirty Filter Alarm Demand Savings

$$\Delta kW = \Delta kWh * CF$$

Table 47. Dirty Filter Alarm Input Values

Input	Value	Source
kW Motor	0.5	Appendix I
EFLH heat	1496	Appendix I
EFLH cool	869	Appendix I

[12] National Renewable Energy Laboratory (NREL). *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Chapter 6: Residential Lighting Protocol. October, 2017. https://www.nrel.gov/docs/fy17osti/68562.pdf.*

Input	Value	Source
EI	0.15	Appendix I
ISR	0.44	PY2019 Survey
Coincidence Factor (CF)	0.000466081	Appendix I
%Heating	0.9565	Appendix I
%Cooling	0.9565	Appendix I
Leakage	0.72	PY2019 Survey

kW Motor = Average motor full load electric demand (kW)

EFLH heat = Equivalent full load hours heating (hours/year)

EFLH cool = Equivalent full load hours cooling (hour/year)

EI = Percentage of energy efficient change.

ISR = In service rate, percentage of units rebated that are actually in service.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

%Heating = Percentage of heating that used the filter

%Cooling = Percentage of cooling that uses the filter

Leakage = Leakage rate, units installed outside of Ameren MO territory.

Energy Efficient Kit Pipe Insulation Wrap Saving Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit Pip Insulation Wrap measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 38. Pipe Insulation Energy Savings

$$\Delta kWh = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Equation 39. Pipe Insulation Demand Savings

$$\Delta kW \quad = \Delta kWh * CF$$

Table ies

Input	Value	Source
Cbase	.1964	Appendix I

Input	Value	Source
Rbase	1	Appendix I
CEE	.458	Deemed Savings Table
REE	4.54	Deemed Savings Table
L	1	Appendix I
ΔT	60	Appendix I
Hours	8766	Appendix I
ηDHW_{Elec}	.98	Appendix I
Coincidence Factor (CF)	.0000887318	Appendix I
ISR	0.56	PY2019 Survey
%Electric	0.42	PY2019 Survey
Leakage	0.72	PY2019 Survey

Cbase = Circumference (Feet) of uninsulated pipe

Rbase = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of uninsulated pipe.

CEE = Circumference of insulated pipe

REE = Thermal resistance coefficient (hr-°F-ft^2)/Btu) of insulated pipe.

L = Length of pipe from water heating source covered by pipe wrap (ft).

ΔT = Average temperature difference (°F) between supplied water and outside air

Hours = Hours per year

ηDHW_{Elec} = Recovery efficiency of electric hot water heater

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

ISR = In service rate, percentage of units rebated that are actually in service.

%Electric = Percentage of hot water heaters that are electric.

Leakage = Leakage rate, units installed outside of Ameren MO territory.

Net Impact Methodology and Results

Participant Free Ridership

The free ridership (FR) assessment for the kits program is calculated differently for lighting and non-lighting measures.

Lighting FR Methodology

The lighting FR algorithm consists of two components:

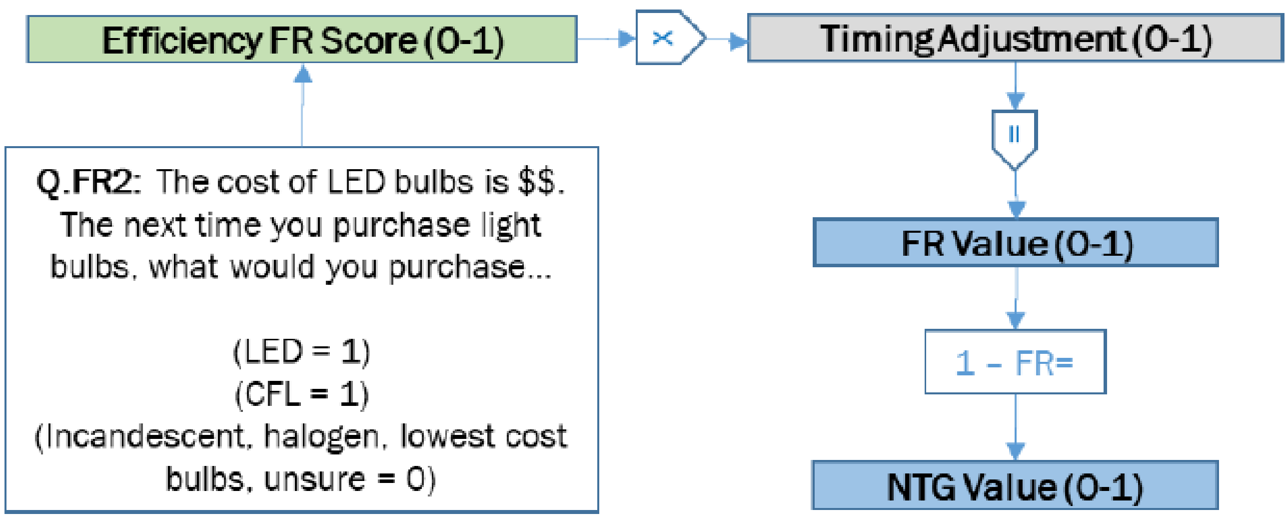
- An Efficiency Score, based on the participant's perception of the program's influence on the decision to install an energy efficient bulb; and
- A Timing Adjustment assessing whether or not the participant would have replaced WORKING bulbs or waited for them to burn out. This is asked only of those participants that state they would have purchased an efficient bulb in the absence of the program.

When scored, each component assesses the likelihood of FR on a scale of 0 to 10, with the two scores averaged and for a combined total FR score. FR is the mean of the two components:

$$Free\ Ridership\ (FR) = \ Efficiency\ FR\ Score\ \times\ Timing\ Adjustment$$

Figure 6 presents a diagram of the FR algorithm we will use, including references to question numbers.

Figure 13. School Kits Program Lighting Free Ridership Algorithm



Calculation of the Efficiency Score

To develop the Efficiency FR Score, the online survey asks about the parent's likely next lighting purchase, had they not received the kit (Q.FR2). Based on this response, we develop an FR efficiency score for each respondent. FR scores for lighting measures can be either 0 or 1, where 0 means no FR (i.e., full credit for the program) and 1 means full FR (i.e., no credit for the program).

The "Next Lighting Purchase (Q.FR2)" question provides participants with the costs of energy efficient lighting options (i.e., LEDs or CFLs) and asks what light bulb they would have purchased the next time that they needed to buy light bulbs. We will reference current retail pricing for the LEDs provided in the kits.

Participants who say they would have purchased efficient bulbs, either LEDs or CFLs, are assigned an efficiency score of 1. Participants who would have purchased less efficient bulbs (i.e., incandescent or halogens) or the lowest cost bulb available, which we assume to be less efficient, are assigned a value of 0:

1 = LED or CFL

0 = Incandescent, halogen, or lowest cost bulbs

Calculation of the Timing Adjustment Factor

Even if the Energy Efficiency Kits Program does not influence the efficiency of bulbs that a customer uses, it could impact the timing of their use by encouraging customers to replace less efficient working light bulbs with LEDs. If this is the case, the program effectively accelerates customers' installation of LEDs and therefore deserves a credit. The survey asks respondents who say they would have purchased LEDs or CFLs the next time they purchased light bulbs, whether receiving the LEDs as part of the kit caused them to replace working light bulbs (Q.FR4). We apply a timing adjustment to the Efficiency FR Score for customers who say they would not have replaced working bulbs on their own but would have waited for the bulbs to burn out. The timing adjustment reduces the Efficiency FR Score by 50%. The adjustment of 50% is based on an assumption that replaced incandescent bulb was half-way through its effective useful life (EUL) of 1 year and that the program accelerated the adoption of energy efficient LEDs by half the EUL (half a year).

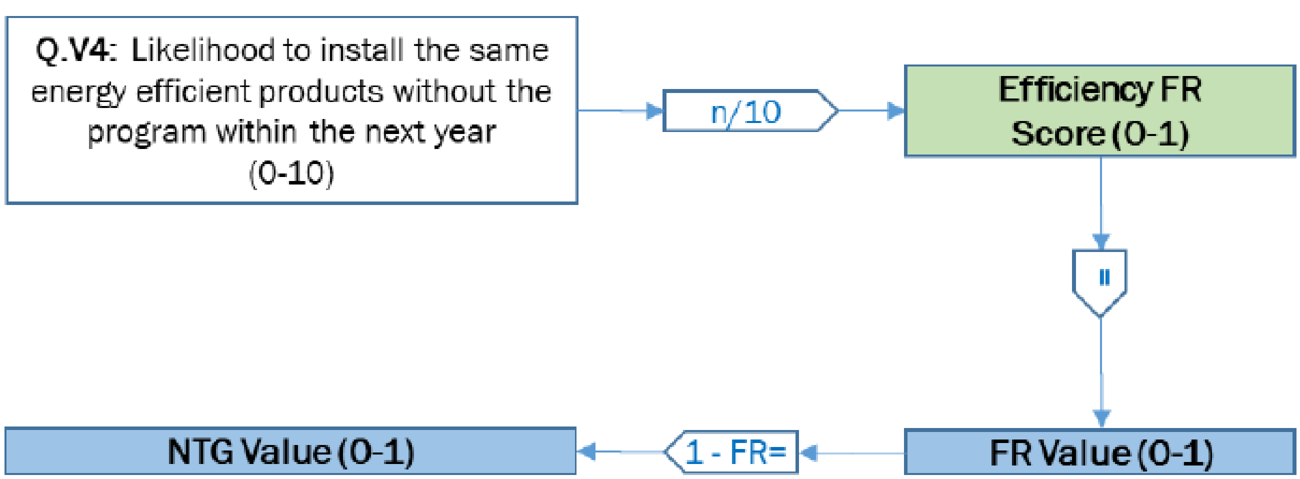
Non-Lighting FR Methodology

The non-lighting FR algorithm does not include a timing adjustment due to the nature of the measures. Because the non-lighting measures are not items that wear out or that customers routinely replace, the program theory does not support early replacement. The FR result is the Efficiency Score.

$$Free\ Ridership\ (FR) = \ Efficiency\ FR\ Score$$

Figure 17 presents a diagram of the FR algorithm we will use, including references to question numbers.

Figure 14: School Kits Program Non-Lighting Free Ridership Algorithm



Calculation of the Efficiency Score

To develop the Efficiency FR Score, the online survey asks about the likelihood to install energy efficient products without the program (Q.V4). Participants are asked to rate (on a scale of 0 to 10) the likelihood that they would have purchased each of the energy efficient products included in the kit on their own within a year. The Efficiency FR Score is calculated as:

$$\text{Likelihood to install without the program} \div 10$$

Free Ridership Results

The free ridership analysis was calculated on a measure level for the School Kits program. A total of 129 parent responses were used in the free ridership analysis for all measures (bathroom and faucet aerators, LED light bulbs, low flow showerheads, a furnace dirty filter alarm, and hot water pipe insulation). LED light bulbs had the highest free ridership (64%), followed by Low Flow Showerheads (32%), and hot water pipe insulation (31%).

Participants' FR -related survey responses show the following:

Lighting Results

- **Efficiency:** Had they not received the bulbs through the School Kit, 57% of respondents stated they would purchase LEDs the next time they needed to buy bulbs, and 2% stated they would purchase CFLs.
- **Timing:** Responses to the timing questions show that the program was responsible for accelerating the timing for purchasing energy efficient bulbs. Seventy five percent of respondents that stated they would have purchased LEDs the next time they needed to buy bulbs, stated they would have waited until the exiting bulbs burned out.

Non-lighting Results

- **Efficiency:** FR scores range from 15-32% for non-lighting measures, which translates to the likelihood participants rated they would have installed the item within the next year in absence of being gifted the kit.

Spillover

A total of 129 participants completed the SO questions in the parent survey and were included in the PSO analysis. The majority of these participants did not install any additional energy efficiency measures without receiving an incentive (80%) or did install additional measures but were not influenced by the program (17%). Four survey respondents (3%) qualified for PSO.

We calculated spillover savings values using measure-level algorithms and assumptions from primarily MO TRM Volume 3, and IL TRM v8 when the MO TRM did not provide all necessary inputs. Table 31 summarizes the results of the measure-level SO analysis.

Table 49. Summary of Measure-Level Participant Spillover[13]

	Measure	Count	kWh
#1	Advanced Power Strips	1	59.20
#2	EE Heating and Cooling Equipment	1	415.06
#3	EE Refrigerator or Freezer	1	58.20
#4	Upgraded Insulation	3	773.07
#5	Window and Door Weather-stripping	2	604.07
	TOTAL	8	1.909.60

To estimate total SO for the PY2019 participant population (3.47%), we divided the estimated total SO in our sample (1,909.60 kWh) by total program ex-post gross savings of the overall participant sample (54,962.94 kWh), as shown in (see Equation 59).

Equation 40. PY2019 [Program Name] Participant Spillover Rate

$$PSO\ \%_{Energy} = \frac{Total\ participant\ sample\ SO\ (kWh)}{Total\ participant\ sample\ savings\ (\mathrm{kWh})} = \frac{1{,}909.60\ kWh}{54{,}962.94\ \mathrm{kWh}} = 3.47\%$$

Multifamily Market Rate (MFMR)

Gross Impact Methodology

Lighting Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Market Rate lighting measures, the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

Enduses were miscategorized and did not consistently match the Measure Description. For example, AC Tune-up measures were categorized as Water heating, Lighting, Cooling, and HeatCool. For reporting, the evaluation team mapped each Measure Description to an enduse.

Table 50. PY2019 Multifamily Market Rate Evaluation Remapping

Measure Description	Enduse
Common Areas Business Custom Measure Ext Lighting BUS	Lighting BUS
Directional LED-MFMR	Lighting BUS
Exit Sign-MFMR	Lighting BUS
Kitchen Aerator-MFMR	Water Heating Res
Learning Thermostat-Multifamily Market Rate	HVAC BUS
LED - 10W (Halogen baseline) - MFMR	Lighting RES

[13] Two respondents also reported energy efficiency lighting upgrades which qualified for participant spillover. The evaluation team is not included these responses due to concerns regarding double counting lighting spillover savings with savings from the retail lighting offering.

Measure Description	Enduse
LED - 12W (Halogen baseline) - MFMR	Lighting RES
LED Fixture-MFMR	EXT Lighting BUS
Bathroom Faucet Aerator -MFMR	Water Heating Res
Low Flow Showerheads - MFMR	Water Heating Res
Omnidirectional LED-MFMR	Lighting BUS
TLED-MFMR	Lighting BUS

The enduse is identical to the original enduse reported in the tracking data, except for the enduse "Miscellaneous Bus" which was mapped to the enduse "Lighting BUS." This selection was made because the measure reported wattage values.

The team used the following equations to calculate electric energy and demand savings:

Equation 41. Lighting Energy and Demand Savings Equations

$$kWh = (Watts_{Base} - Watt_{EE}) \times ISR \times (1 - LKG) \times (Hours \times WHF)/1{,}000$$

$$kW = kWh \times CF$$

Lighting	Enduse	Verified Inputs	Verified Source
WattsBase	EXT Lighting BUS	Custom. 500 W when WattsEE = 84 (estimated by looking at other WattsBase/WattsEE pairings for exterior lighting)	Tracking Data
	Lighting BUS	Custom	Tracking Data
	Lighting Res	Custom	Tracking Data
WattsEE	EXT Lighting BUS	Custom	Tracking Data
	Lighting BUS	Custom	Tracking Data
	Lighting Res	Custom	Tracking Data
ISR	EXT Lighting BUS	0.987	Appendix I
	Lighting BUS	0.987	Appendix I
	Lighting Res	0.9818	Appendix I
Hours	EXT Lighting BUS	2,876	Appendix H for Midrise Apartment - Building
	Lighting BUS	8,766 (exit sign), 2,876 (others)	Appendix H for Exit Signs. Appendix H for Midrise Apartment – Building.
	Lighting Res	728	Appendix I
WHF	EXT Lighting BUS	1	Appendix I
	Lighting BUS	1.14	Appendix H
	Lighting Res	0.88	Appendix I
CF	EXT Lighting BUS	0.0000056	Appendix I - CF for nonresidential. No CF provided in TRM for exterior.
	Lighting BUS	0.0001900	Appendix I - CF for nonresidential.
	Lighting Res	0.0001493	Appendix I

Hot Water Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Market Rate hot water measures (aerators, showerheads), the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 42. Low Flow Faucet Aerator Energy and Demand Savings Equations

$$kWh = \%ElectricDHW \times ((GPM_{base} \times L_{base} - GPM_{low}) \times Household \times 365.25 \times \frac{DF}{FPH}) \times EPG_{electric} \times ISR$$

$$kW = kWh \times CF$$

Bathroom Faucet Aerator	Verified Inputs	Verified Source
%ElectricDHW	1	Appendix I
GPM_base	2.2	Preliminary Data measure description
L_base	1.6	Appendix I
GPM_low	0.5	Tracking Data
L_low	1.6	Appendix I
Household	1.56	Appendix I
DF	0.9	Appendix I
FPH	1.86	Appendix I
EPG_electric	0.062703693	Appendix I
ISR	0.95	Appendix I
CF	8.873E-05	Appendix I

Kitchen Faucet Aerator	Verified Inputs	Verified Source
%ElectricDHW	1	Appendix I
GPM_base	2.2	Preliminary Data measure description (used bathroom aerator baseline, no kitchen aerator baseline was provided in preliminary data)
L_base	4.5	Appendix I
GPM_low	1.5	Tracking Data
L_low	4.5	Appendix I
Household	1.56	Appendix I
DF	0.75	Appendix I
FPH	1.19	Appendix I
EPG_electric	0.062703693	Appendix I
ISR	0.95	Appendix I
CF	8.873E-05	Appendix I

Equation 43. Low Flow Faucet Aerator Energy and Demand Savings Equations

$$kWh = \%ElectricDHW \times ((GPM_{base} \times L_{base} - GPM_{low}) \times Household \times 365.25 \times \frac{SPCD}{SPH}) \times EPG_{electric} \times ISR$$

$$kW = kWh \times CF$$

Low Flow Showerhead	Ex Ante Source	Verified Inputs	Verified Source
%ElectricDHW		1	Appendix I
GPM_base		2.5	Preliminary Data measure description
L_base		7.8	Appendix I
GPM_low		1.25	Tracking Data
L_low		7.8	Appendix I
Household		1.52	Appendix I
SPCD		0.6	Appendix I
FPH		1	Appendix I
EPG_electric		0.1	Appendix I
ISR		1	Appendix I
CF		8.873E-05	Appendix I

Learning Thermostat Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Market Rate learning thermostat measures the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 44. Learning Thermostat Energy and Demand Savings Equations

$$kWh = kWh_{Heating} + kWh_{Cooling}$$

$$kWh_{Heating} = \%ElectricHeat \times HeatingConsumption_{Electric} \times HF \times HeatingReduction \times ISR + (\Delta Therms \times Fe \times 29.3)$$

$$kWh_{Cooling} = \%AC \times \left(\frac{EFLH_{Cool} \times CapacityCool \times \frac{1}{SEER}}{1000} \right) \times CoolingReduction \times ISR$$

$$\Delta Therms = \%FossilHeat \times HeatingConsumption_{Gas} \times HF \times HeatingReduction \times ISR$$

$$kW = kWh_{Cooling} \times CF$$

Learning Thermostat	Verified Inputs	Verified Source
%ElectricHeat	1	Appendix I
HeatingConsumption_Electric	11,456	Appendix I
HF	0.65	Appendix I
HeatingReduction	0.088	Tracking Data (assumes Manual replacement)
Eff_ISR	1	Appendix I
deltaTherm	0	Assume electric heating
%AC	1	Assume AC present
EFLH_cool	869	Appendix I
Capacity_cool	24,000	Tracking Data
SEER	8	Tracking Data
CoolingReduction	0.08	Appendix I
CF	0.000947418	Appendix I

Appliance Recycling (RAR)

Gross Impact Methodology

Refrigerator Recycling Regression Analysis

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program refrigerator measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 45. Refrigerator recycling regression-based analysis for calculating electric savings

$$\Delta kWh_{Unit} = \Big[0.5822 + (Age * 0.0269) + (Pre - 1990 * 1.0548) + (Size * 0.0673) + (Side - by - side * 1.0706) + (Single - door * -1.9767) + (Primary\ Usage * 0.6046) + \left(\frac{CDD}{365} * unconditioned * 0.0200\right) + \left(\frac{HDD}{365} * unconditioned * -0.0447\right)\Big] * Days * Part\ Use\ Factor$$

Equation 46. Refrigerator recycling regression-based analysis for calculating demand savings.

$$\Delta kW = \Delta kWh_{unit} * CF$$

Where:

Table 51. Refrigerator Input Values

Input	Value	Source
Age	Tracking data value	Tracking data
Pre-1990	Tracking data value	Tracking data
Size	Tracking data value	Tracking data
Side-by-Side	Tracking data value	Tracking data
Single – Door	Tracking data value	Tracking data
Primary Usage	Tracking data value/Participant survey	PY2019 Survey
CDD	1678	Appendix I
HDD	4486	Appendix I
Unconditioned	Tracking data value/Participant survey	PY2019 Survey
Days	365	Appendix I
Part Use Factor (PUF)	Tracking data value/Participant survey	Py2019 Survey
(CF)	0.000128525	Appendix I

Age = Age of retired unit

Pre -1990 = Designator of 1 if the unit was manufactured prior to 1990

Size = Capacity (Cubic Feet) or retired unit

Side – by – Side = Refrigerator specific characteristic

Single – Door = Refrigerator specific characteristic

Primary Usage = Retired unit primary or secondary unit

CDD = Cooling degree days

Unconditioned = Retired unit operated in a conditioned space

HDD = Heating Degree days

Part Use Factor (PUF) = To account for the units that do not run throughout the entire year.

Coincidence Factor = Summer peak coincidence period (kW) to annual energy (kWh) factor.

Freezer Recycling Regression Analysis

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program freezer measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 47. Freezer recycling regression-based analysis for calculating electric savings.

$$\Delta kWh_{Unit} = [-0.8918 + (Age * 0.0384) + (Pre-1990 * 0.6952) + (Size * 0.1287) + (Chest\ Freezer * 0.3503) + (CDD/365 * unconditioned * 0.0695) + (HDD/365 * unconditioned * -0.0313)] * Part\ Use\ Factor$$

Equation 48. Freezer recycling regression-based analysis for calculating demand savings.

$$\Delta kW = \Delta kWh_{unit} * CF$$

Input	Value	Source
Age	Tracking data value	Tracking data
Pre-1990	Tracking data value	Tracking data
Size	Tracking data value	Tracking data
Chest freezer	Tracking data value	Tracking data
CDD	1678	Appendix I
HDD	4486	Appendix I
Unconditioned space	Tracking data value/Participant survey	PY2019 Survey

Input	Value	Source
Days	365	Appendix I
Part Use Factor (PUF)	Tracking data value/Participant survey	PY2019 Survey
Coincidence Factor (CF)	.000128525	Appendix I

Age = Age of retired unit

Pre -1990 = Designator of 1 if the unit was manufactured prior to 1990

Size = Capacity (Cubic Feet) or retired unit

Chest Freezer = Freezer specific unit characteristic

CDD = Cooling degree days

Unconditioned = Retired unit operated in a conditioned space

HDD = Heating Degree days

Part Use Factor (PUF) = To account for the units that do not run throughout the entire year.

Coincidence Factor = Summer peak coincidence period (kW) to annual energy (kWh) factor.

Room AC Recycling Deemed Savings

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program room AC measure, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings values.

The team used the following electric and demand savings values:

Table 52. Room AC Deemed Savings Values

	Value		Source
Electric	302.53	kWh	Appendix I
Demand	0.286	kW	Appendix I

Dehumidifier Recycling Deemed Savings

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program dehumidifier measure, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings values.

The team used the following electric and demand savings values:

Table 53. Dehumidifier Deemed Saving Values

	Value		Source
Electric	139	kWh	Appendix I

	Value		Source
Demand	0.0648	kW	Appendix I

Energy Efficient Kit Faucet Aerator Saving Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit faucet aerator measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 49. EE Kit Faucet Aerator electric savings equation.

$$\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * 365.25 * DF / FPH) * EPG\_electric * ISR$$

Equation 50. EE Kit Faucet Aerator demand savings equation.

$$\Delta kW = \Delta kWh * CF$$

Table 54. Faucet Aerator Input Values

Input	Bathroom	Kitchen	Source
%ElectricDHW	0.42	0.42	PY2019 Survey
GPM_base	2.2	2.2	Appendix I
L_base	1.6	4.5	Appendix I
GPM_low	1.5	1.5	Appendix I
L_low	1.6	4.5	Appendix I
Household	2.65	2.65	PY2019 Survey
DF	0.9	0.75	Appendix I
FPH	2.2839	1.1875	Appendix I
EPG	0.061532	0.0789712	Appendix I
ISR	0.24	0.2	PY2019 Survey
Coincidence Factor (CF)	0.0000887318	0.00008873118	Appendix I

%ElectricDHW = Proportion of water heating supplied by electric resistance heating.

GPM_Base = Average flow rate, in gallons per minute, of the baseline faucet “as-used.”.

L_base = Average baseline length of daily faucet use per capita in minutes.

GPM_Low = Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”.

L-Low = Average retrofit daily length faucet use per capita for faucet of interest in minutes.

Household = Average number of people per household

DF = Drain Factor

FPH = Faucets per Home

EPG = Energy per gallon of water used by faucet supplied by electric water heater

ISR = In Service rate of faucet aerators

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Energy Efficient Kit Low Flow Shower Head Saving Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit low flow shower head measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 51. Low Flow Shower Head Energy Savings.

$$\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * SPCD * 365.25 / SPH) * EPG\_electric * ISR$$

Equation 52. Low Flow Shower Head Demand Savings.

$$\Delta kW = \Delta kWh * CF$$

Table 55. Low Flow Shower Head Input Values.

Input	Value	Source
%ElectricDHW	0.42	PY2019 Survey
GPM_base	2.35	Appendix I
L_base	7.8	Appendix I
GPM_low	1.5	Appendix I
L_low	7.8	Appendix I
Household	2.65	PY2019 Survey
SPCD	.832	PY2019 Survey
SPH	2.14	PY2019 Survey
EPG	0.1088	Appendix I
ISR	0.24	PY2019 Survey
Coincidence Factor (CF)	0.000088732	Appendix I

%ElectricDHW = Proportion of water heating supplied by electric resistance heating.

GPM_Base = Average flow rate in gallons per minute of the baseline showerhead.

L_base = Shower length in minutes with baseline showerhead

GPM_Low = Average flow rate in gallons per minute of the low-flow showerhead.

L-Low = Shower length in minutes with low-flow showerhead

Household = Average number of people per household

SPCD = Shower per capita per day

SPH = Showerheads per household so that per showerhead savings fractions can be determined

EPG = Energy per gallon of hot water supplied by electric

ISR = In service rate of showerhead

Coincidence Factor = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Energy Efficient Kit LED – 10W (Halogen Baseline) Savings Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit 10W LED measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 53. LED Lighting Energy Savings.

$$\Delta kWh_{RES} =$$

$$(Watt_{Base} - Watt_{EE}) * \%RES * ISR * (1 - LKG) * (Hours_{RES} * WHF_{RES}) /1{,}000$$

Equation 54. LED Lighting Demand Savings

$$\Delta kW = \Delta kWh * CF$$

Table 56. LED Lighting Input Values.

Input	Value	Source
Watts Base	43	Appendix I
Watts EE	9	Appendix I
ISR (cumulative)	0.879	PY2019 Survey
Hours Res	996.45	Appendix I
WHF	0.99	Appendix I
Coincidence Factor (CF)	0.000149253	Appendix I
%Res	1	Appendix I
Leakage	0	PY2019 Survey

Watts Base = Wattage of the baseline bulb that was installed prior to the efficient bulb

Watts EE = Wattage of efficient light bulb

% Res = Percentage of light bulbs handed out to residential customers

ISR = In service rate, percentage of units rebated that are actually in service based on estimated future installation rate trajectory.

Leakage = Leakage rate, units installed outside of Ameren Missouri territory.

Hours Res = Average hours of use per year.

WHF = Waste heat factor for energy to account for electric heating increase from the reduction of waste heat from efficient lighting.

Coincidence Factor = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

LED In-Service Rate

We estimated the ISRs for LEDs offered through kits component of the RAR Program using the installation trajectory approach recommended by the UMP.[14] Similar to our approach to estimating ISRs for the Residential Lighting Program, we developed both a first year ISR and cumulative ISR reflecting future installations over a six year period (see Residential Lighting Gross Impact Methodology Section). The first year and cumulative ISRs for LEDs provided through the RAR are presented in Table 57 below.

Table 57. First Year and Future Trajectory ISR for RAR LEDs

First Year ISR	Cumulative ISR
0.656	0.879

Energy Efficient Kit Dirty Filter Alarm Savings Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit Dirty Filter Alarm measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 55. Dirty Filter Alarm Energy Savings

$$kWh\ Heating\ Savings = kW_{motor} * FLH_{heat} * EI * ISR$$

$$kWh\ Cooling\ Savings = kW_{motor} * FLH_{cool} * EI * ISR$$

Equation 56. Dirty Filter Alarm Demand Savings

$$\Delta kW = \Delta kWh * CF$$

Table 58. Dirty Filter Alarm Input Values

Input	Value	Source
kW Motor	0.5	Appendix I
EFLH heat	1496	Appendix I
EFLH cool	869	Appendix I
EI	0.15	Appendix I

[14] National Renewable Energy Laboratory (NREL). *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Chapter 6: Residential Lighting Protocol. October, 2017. https://www.nrel.gov/docs/fy17osti/68562.pdf.*

Input	Value	Source
ISR	0.09	PY2019 Survey
Coincidence Factor (CF)	0.000466081	Appendix I
%Heating	0.9565	Appendix I
%Cooling	0.9565	Appendix I

kW Motor = Average motor full load electric demand (kW)

EFLH heat = Equivalent full load hours heating (hours/year)

EFLH cool = Equivalent full load hours cooling (hour/year)

EI = Percentage of energy efficient change.

ISR = In service rate, percentage of units rebated that are actually in service.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor.

%Heating = Percentage of heating that used the filter

%Cooling = Percentage of cooling that uses the filter

Energy Efficient Kit Pipe Insulation Wrap Saving Assumption

To calculate verified gross energy and demand savings for PY2019 Appliance Recycling Program EE Kit Pipe Insulation Wrap measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

Equation 57. Pipe Insulation Energy Savings.

$$\Delta kWh = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Equation 58. Pipe Insulation Demand Savings

$$\Delta kW \quad = \Delta kWh * CF$$

Table 59. Pipe Insulation Input Values

Input	Value	
Cbase	0.1964	Appendix I
Rbase	1	Appendix I
CEE	0.458	Appendix I
REE	4.54	Appendix I
L	1	Appendix I
ΔT	60	Appendix I
Hours	8766	Appendix I
ηDHW_{Elec}	0.98	Appendix I

Input	Value	
Coincidence Factor (CF)	0.0000887318	Appendix I
ISR	0.41	PY2019 Survey
%Electric	0.42	PY2019 Suvey

Cbase = Circumference (Feet) of uninsulated pipe

Rbase = Thermal resistance coefficient (hr-°F-ft²)/Btu) of uninsulated pipe.

CEE = Circumference of insulated pipe

REE = Thermal resistance coefficient (hr-°F-ft²)/Btu) of insulated pipe.

L = Length of pipe from water heating source covered by pipe wrap (ft).

ΔT = Average temperature difference (°F) between supplied water and outside air

Hours = Hours per year

ηDHW_{Elec} = Recovery efficiency of electric hot water heater

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

ISR = In service rate, percentage of units rebated that are actually in service.

%Electric = Percentage of hot water heaters that are electric.

Net Impact Methodology and Results

Participant Free Ridership

Three independent free ridership (FR) methods are used for the Appliance Recycling program:

1) Appliances
2) Kit lighting measures (LED bulbs)
3) Kit non-lighting measures (bathroom and faucet aerators, low flow showerheads, a dirty furnace filter alarm, and hot water pipe insulation).

Algorithm specifics for each method are detailed here:

Appliance FR Methodology

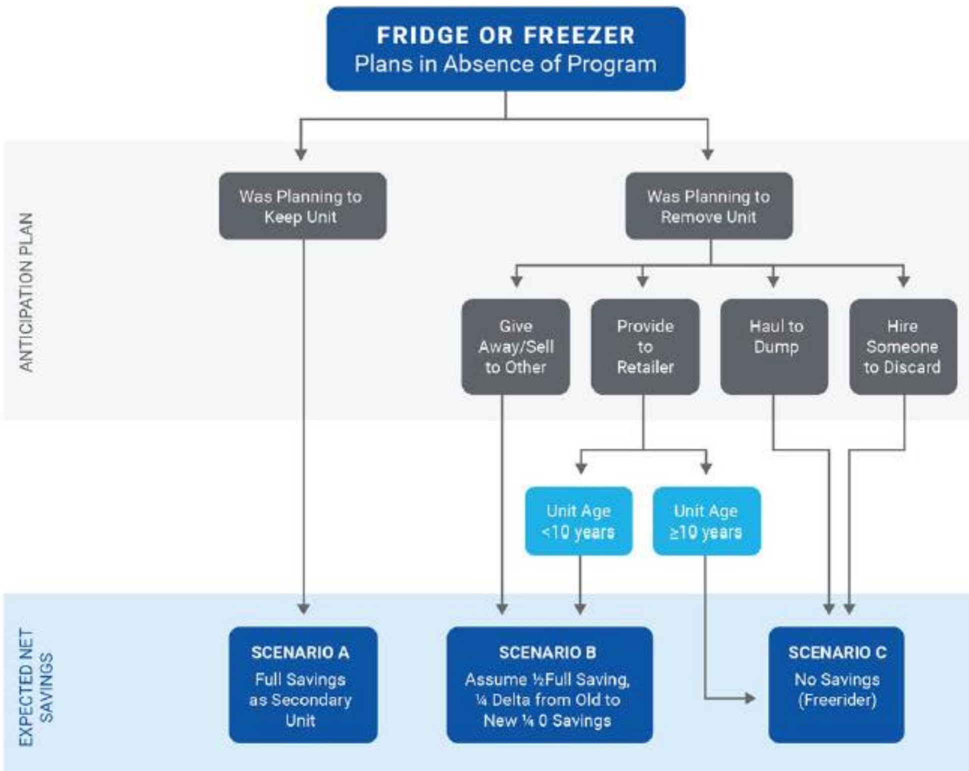
The Appliance FR assessment is based on the IL TRM v7.0 protocol and is a multi-step process that segments participants into different groups, each with specific attributable savings. The applicable groupings are:

- The appliance would have been kept by the participating household (not a free rider)
- The appliance would have been discarded in a way that transfers the unit to another customer for continued use (see Figure 1)
- The appliance would have been discarded in a way that would have permanently removed the unit from service. (free rider)

Categorizing customers into these groupings is achieved via a self-report email survey. When scored, participants either fall into three different categories with an associated impact on savings. Follow-up questions are included to validate the viability of responses. Figure 15 presents a diagram of the FR algorithm and associated impacts to savings.

Figure 15. Appliance Recycling Program Free Ridership Algorithm (Appliances. Source: IL TRM)

Figure 4-2. Appliance Retirement Scenarios



Source: Adapted from the Pennsylvania Statewide Evaluator Common Approach for Measuring Net Savings for Appliance Retirement Programs, Guidance Memo-026, March 14, 2014.

Energy Efficiency Kits FR Methodology

The lighting FR algorithm consists of two components:

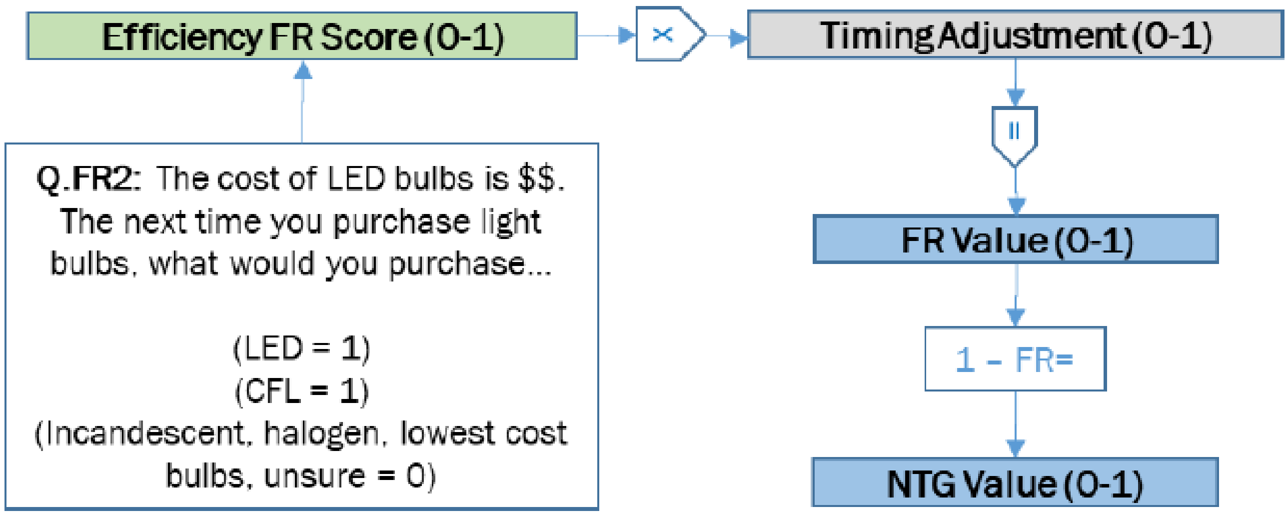
- An Efficiency Score, based on the participant's perception of the program's influence on the decision to install and energy efficient bulb; and
- A Timing Adjustment assessing whether or not the participant would have replaced WORKING bulbs or waited for them to burn out. This is asked only of those participants that state they would have purchased an efficient bulb in the absence of the program.

When scored, each component assesses the likelihood of FR on a scale of 0 to 10, with the two scores averaged and for a combined total FR score. FR is the mean of the two components:

$$Free\ Ridership\ (FR) = Efficiency\ FR\ Score\ \times Timing\ Adjustment$$

Figure 16 presents a diagram of the FR algorithm we will use, including references to question numbers.

Figure 16. Appliance Recycling Kits Lighting Free Ridership Algorithm



Calculation of the Efficiency Score

To develop the Efficiency FR Score, the online survey asks about the participant's likely next lighting purchase, had they not received the kit (Q.FR2). Based on this response, we will develop an FR efficiency score for each respondent. FR scores for lighting measures can be either 0 or 1, where 0 means no FR (i.e., full credit for the program) and 1 means full FR (i.e., no credit for the program).

The "Next Lighting Purchase (Q.FR2)" question provides participants with the costs of energy efficient lighting options (i.e., LEDs or CFLs) and asks what light bulb they would have purchased the next time that they needed to buy light bulbs. We will reference current retail pricing for the LEDs provided in the kits. Participants who say they would have purchased efficient bulbs, either LEDs or CFLs, are assigned an efficiency score of 1. Participants who would have purchased less efficient bulbs (i.e., incandescent or halogens) or the lowest cost bulb available, which we assume to be less efficient, are assigned a value of 0:

1 = LED or CFL

0 = Incandescent, halogen, or lowest cost bulbs

Calculation of the Timing Adjustment Factor

Even if the Energy Efficiency Kits Program does not influence the efficiency of bulbs that a customer uses, it could impact the timing of their use by encouraging customers to replace less efficient working light bulbs with LEDs. If this is the case, the program effectively accelerates customers' installation of LEDs and therefore deserves a credit. The survey asks respondents who say they would have purchased LEDs or CFLs the next time they purchased light bulbs, whether receiving the LEDs as part of the kit caused them to replace working light bulbs (Q.FR4). We will apply a timing adjustment to the Efficiency FR Score for customers who say they would not have replaced working bulbs on their own but would have waited for the bulbs to burn out. The timing adjustment reduces the Efficiency FR Score by 50%. The adjustment of 50% is based on an assumption that replaced incandescent bulb was half-way through its effective useful life (EUL) of 1 year and that the program accelerated the adoption of energy efficient LEDs by half the EUL (half a year).

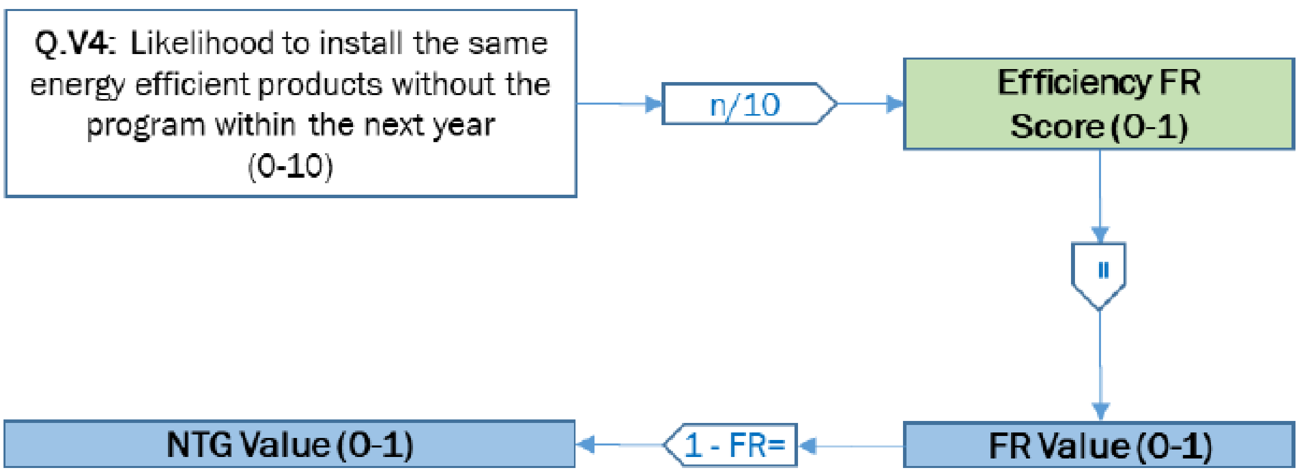
Non-Lighting FR Methodology

The non-lighting FR algorithm does not include a timing adjustment due to the nature of the measures. Because the non-lighting measures are not items that wear out or that customers routinely replace, the program theory does not support early replacement. The FR result is the Efficiency Score.

$$Free\ Ridership\ (FR) = \ Efficiency\ FR\ Score$$

Figure 17 presents a diagram of the FR algorithm we will use, including references to question numbers.

Figure 17. Appliance Recycling Kits Non-lighting Free Ridership Algorithm



Calculation of the Efficiency Score

To develop the Efficiency FR Score, the online survey asks about the likelihood to install energy efficient products without the program (Q.V4). Participants are asked to rate (on a scale of 0 to 10) the likelihood that they would have purchased each of the energy efficient products included in the kit on their own within a year. The Efficiency FR Score is calculated as:

Likelihood to install without the program ÷ 10

Free Ridership Results

Appliance Results

The free ridership analysis was calculated on a measure level for the Appliance Recycling program. A total of 189 responses were used in the free ridership analysis for refrigerators (143) and freezers (46). Secondary recycled appliances such as room air conditioners were not included in the sample due to low population counts. The free ridership rate for refrigerators resulted in 63%, and 58% for freezers. The savings weighted average of the two appliances was used for room air conditioners and dehumidifiers.

Participants' FR -related survey responses show the following:

Table 60: NTG Survey Derived Participant Action in Absence of the Program

FR Scenario	Acton	% of respondents
A	Planned keep unit (full savings)	18%
B	Planned to give away (partial savings)	36%
C	Planned to trash/recycle (no savings)	46%

Energy Efficiency Kit Results

The free ridership analysis was calculated on a measure level for the Energy Efficiency Kits. A total of 170 parent responses were used in the free ridership analysis all measures (bathroom and faucet aerators, LED light bulbs, low flow showerheads, a furnace dirty filter alarm, and hot water pipe insulation). LED light bulbs had the highest free ridership (40%), followed by hot water pipe insulation (34%), and low flow showerheads.

Participants' FR -related survey responses show the following:

Lighting Results

- **Efficiency:** Had they not received the bulbs through the School Kit, 66% of respondents stated they would purchase LEDs the next time they needed to buy bulbs, and 5% stated they would purchase CFLs.
- **Timing:** Responses to the timing questions show that the program was responsible for accelerating the timing for purchasing energy efficient bulbs. Sixty five percent of respondents that stated they would have purchased LEDs the next time they needed to buy bulbs, 33% stated they would have waited until the exiting bulbs burned out.

Non-lighting Results

- **Efficiency:** FR scores range from 15-34% for non-lighting measures, which translates to the likelihood participants rated they would have installed the item within the next year in absence of being gifted the kit.

Spillover

A total of 384 participants completed the SO questions in the parent survey and were included in the PSO analysis. Twenty six percent stated they did install additional energy efficiency measures without receiving an incentive. Eighteen respondents qualified for PSO.

We calculated spillover savings values using measure-level algorithms and assumptions from primarily MO TRM Volume 3, and IL TRM v8 when the MOR TRM did not provide all necessary inputs. Table 61 summarizes the results of the measure-level SO analysis.

Table 61. Summary of Measure-Level Participant Spillover [a]

Spillover Measure	Appliance Quantity (participants)	Kits Quantity (participants)	Total Quantity (participants)	Appliance Savings (kWh)	Kits Savings (kWh)	Total RAR Program Savings (kWh)
Advanced Power Strips	1	0	1	59	-	59
EE Clothes Washer	2	1	3	198	99	297
EE Cooling and Heating Equipment	3	1	4	1,841	614	2,455
EE Dehumidifier	1	0	1	204	-	204
EE Refrigerator or Freezer	4	2	6	233	116	349
EE Water Heater	2	0	2	3,139	-	3,139
Faucet aerators	3	0	3	87	-	87
Installed EE Cooling Equipment	1	0	1	232	-	232
Low-flow Showerheads	6	0	6	488	-	488
Programmable or Smart Thermostat (Central Air Conditioner)	3	1	4	560	187	746
Programmable or Smart Thermostat (Heat Pump)	3	1	4	1,843	614	2,457
Upgraded Insulation	2	0	2	515	-	515
Water Heater Tank Insulation	1	0	1	103	-	103
Window and Door Weather-stripping	3	2	5	906	604	1,510
Total	**35**	**8**	**43**	**10,409**	**2,234**	**12,643**

[a] Fifteen respondents also reported energy efficiency lighting upgrades which qualified for participant spillover. The evaluation team is not included these responses due to concerns regarding double counting lighting spillover savings with savings from the retail lighting offering.

The evaluation team calculated two separate spillover values, one for each survey cohort (the appliance specific survey and the kits specific survey).

Appliance specific spillover: dividing the estimated total SO in our appliance cohort sample (10,409 kWh) by total program ex post gross savings of the overall appliance cohort participant sample (235,610 kWh) yields a SO rate of 4.42% (Equation 59).

Equation 59. PY2019 Appliance Recycling Appliance Cohort Participant Spillover Rate

$$PSO\ \%_{Energy} = \frac{Total\ participant\ sample\ SO\ (kWh)}{Total\ participant\ sample\ savings\ (\mathrm{k}Wh)} = \frac{10{,}409\ kWh}{235{,}610\ \mathrm{k}Wh} = 4.42\%$$

Similarly for RAR **kits specific spillover:** dividing the estimated total SO in our kits cohort sample (2,234 kWh) by total program ex post gross savings of the overall kits cohort participant sample (193,993 kWh) yields a SO rate of 1.15%.

The two spillover rates are averaged with ex-post gross savings of the total appliance and kits participant sample to yield the program level spillover rate of 3.80%.

Single Family Low Income (SF LI)

Gross Impact Methodology

AC Tune-Up Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program AC tune-up measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described below. Heating savings are calculated only for heat pump equipment.

Equation 60. AC Tune-Up Energy and Demand Savings Equations

$$kWh_{Cooling} = \frac{\left(EFLH\_cool \times Capacity\_cool \times \left(\frac{1}{SEER_{TestIn}} - \frac{1}{SEER_{TestOut}}\right)\right)}{1000}$$

$$kWh_{Heating} = \frac{\left(EFLH\_heat \times Capacity\_heat \times \left(\frac{1}{HSPF_{TestIn}} - \frac{1}{HSPF}\right)\right)}{100}$$

$$kW = kWh_{Cooling} \times CF$$

Table 62. AC Tune-Up Input Values for SF LI Measures

Input	Value	Source
EFLH_cool	869	Appendix F
Capacity_cool	Custom (based on measure)	Appendix F
SEER_TestIn	11.9	Appendix F
SEER_TestOut	15.3	Appendix F
EFLH_heat	1,496	Appendix F
Capacity_heat	Custom (based on measure)	Appendix F
HSPF_TestIn	6.3	Appendix F
HSPF_TestOut	6.7	Appendix F
Coincidence Factor (CF)	0.000947418	Appendix F

Advanced Thermostat Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program advanced thermostat measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described in the HVAC section.

Air Sealing Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single-Family Low-Income Program air sealing measures, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

$$\Delta kWh_{heating} = Default_{heat} * Sq.ft.$$

$$\Delta kWh_{cooling} = Default_{cool} * Sq.ft.$$

$$\Delta kW = \Delta kW * CF$$

$$\Delta Therms = Default * Sq.ft.$$

Additional Fan Savings: $\Delta kWh_{heating} = \Delta Therms * F_e * 29.3$

Table 63. Air Sealing Input Values for SF LI Measures

Parameter	Measure	Inputs	Source
Default Heat/Sq. ft	Air Sealing (Infiltration reduction) - 30% SF LI DI electric furnace base	0.308	Appendix F
	Air Sealing (Infiltration reduction) – Gas Heated Home	0.257	Appendix F
Default therm/ Sq ft	Air Sealing (Infiltration reduction) - 30% SF LI DI heat pump base	0.013	Appendix F
Default cool		0.050	Appendix F
Fe		3.14%	Appendix F
CF		0.000460805	Appendix F

Air Source Heat Pump (ASHP) Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program air source heat pump (ASHP) measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described in the HVAC section.

Central Air Conditioner (CAC) Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program central air conditioner (CAC) measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described in the HVAC section.

Ceiling Insulation Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program ceiling insulation measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described below.

Equation 61. Ceiling Insulation Energy and Demand Savings Equations

$$kWh_{HeatingElec} = \frac{\left(\%ElecHeat \times \left(\frac{1}{R_{old}} - \frac{1}{R_{Attic}}\right) \times A_{Attic} \times (1 - FramingFactor_{Attic} \times HDD \times 24 \times Adj_{Attic}\right)}{n_{heat} \times 3412} + (1 - \%ElecHeat) \times \Delta Therms \times F_e \times 29.3$$

$$kWh_{Cooling} = \frac{\left(\%CentralCooling \times \left(\frac{1}{R_{old}} - \frac{1}{R_{Attic}}\right) \times A_{Attic} \times (1 - FramingFactor_{Attic} \times CDD \times 24 \times DUA\right)}{n_{cool} \times 3412}$$

$$\Delta Therms = \frac{\left(\left(\frac{1}{R_{old}} - \frac{1}{R_{Attic}}\right) \times A_{Attic} \times (1 - FramingFactor_{Attic} \times HDD \times 24 \times Adj_{Attic}\right)}{n_{heat} \times 10{,}000}$$

$$kW = kWh_{Cooling} \times CF$$

Table 64. Ceiling Insulation Input Values for SF LI Measures

Ceiling Insulation	Verified Inputs	Verified Source
%ElectricHeat	Custom	Tracking Data
R_old	Custom	Tracking Data (based on measure)
R_attic	Custom	Tracking Data
A_attic	Custom	Tracking Data
FramingFactor_Attic	7%	Appendix F
CDD	1646	Appendix F
DUA	0.75	Appendix F
nCool	11	Appendix F
HDD	4,486	Appendix F
ADJ_Attic	0.74	Appendix F
nHeat	0.71 for Gas Heat 1.0 for Electric Furnace	Appendix F

Ceiling Insulation	Verified Inputs	Verified Source
	1.69 for ASHP	
Fe	3.14%	Appendix F
CF	0.000466081	Appendix F

Dirty Filter Alarm Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program dirty filter alarm measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations and input parameters are described in the Energy Efficiency Kits section, and input values specific to SF LI dirty filter alarm measures are described in the table below.

Table 65. Dirty Filter Alarm Input Values for SF LI Measures

Input	Value	Source
kW Motor	0.5	Appendix F
EFLH heat	1496	Appendix F
EFLH cool	869	Appendix F
EI	15%	Appendix F
ISR	58%	Appendix F
Coincidence Factor (CF)	0.000466081	Appendix F

Duct Sealing Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single-Family Low-Income Program duct sealing and repair measures, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix F deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

$$\Delta kWh = \Delta kWh_{Cooling} + kWh_{Heating}$$

$$\Delta kWh_{Cooling} = Cool\ Savings\ per\ Unit * Duct_{length}$$

$$\Delta kWh_{HeatingElectric} = Heat\ Savings\ per\ Unit * Duct_{length}$$

$$\Delta kWh_{HeatingGas} = \Delta Therms * Fe * 29.3$$

$$\Delta Therms = Heat\ Savings\ per\ Unit * Duct_{length}$$

Table 66. Duct Sealing Input Values for SF LI Measures

Duct Sealing measure	parameter	Verified Input	Verified source
Duct Repair (Sealing) - Electric Heating	Annual cooling savings per unit (kWh/ft)	0.81	Appendix F
	Duct length	Actual	
	Heating Savings per unit (kWh/ft)	4.11	
	CF	0.0004660805	
Duct Repair (Sealing) - Gas Heating	Annual cooling savings per unit (kWh/ft)	0.81	Appendix F
	Duct length	Actual	
	Heating Savings per unit (kWh/ft)	0.21	
	CF	0.0004660805	
Duct Repair (Sealing) - Electric Heating MH Adjusted	Annual cooling savings per unit (kWh/ft)	0.95	Appendix F
	Duct length	Actual	
	Heating Savings per unit (kWh/ft)	5.06	
	CF	0.0004660805	
Duct Repair (Sealing) - Gas Heating MH Adjusted	Annual cooling savings per unit (kWh/ft)	0.95	Appendix F
	Duct length	Actual	
	Heating Savings per unit (kWh/ft)	0.26	
	CF	0.0004660805	

Furnace fan energy consumption percentage = 3.14%

Electronically Commutated Motor (ECM) Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program electronically commutate motor (ECM) measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described in the HVAC section.

Floor Insulation Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single-Family Low-Income Program floor insulation measure, the evaluation team applied the November 2019 Ameren Missouri TRM, Appendix I deemed savings tables and 2019 participant survey answers to the program tracking database.

The team used the following equations to calculate electric and demand energy savings:

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

$$\Delta kWh_{cool} = \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * \ Area * \ (1 - Framing\ Factor) * \ CDD * 24 * \ DUA}{(1000 \ * \ \eta Cool)}$$

$$\Delta kWh_{heat} = \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * \ Area * \ (1 - Framing\ Factor) * \ HDD \ * \ 24 \ * ADJ_{Floor}}{(\eta Heat \ * \ 3412)}$$

$$\Delta therms = \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * \ Area * \ (1 - Framing\ Factor) * \ HDD \ * \ 24 \ * ADJ_{Floor}}{(\eta Heat \ * \ 100{,}000)}$$

Table 67. Floor Insulation Input Values for SF LI Measures

Floor Insulation	Verified Inputs	Verified Source
R_{Old}	3.96	Appendix I
R_{Added}	25	Appendix I
Area	Actual	Tracking Data
Framing Factor	12%	Appendix I
24	Converts hours to days	Appendix I
CDD	762	Appendix I
DUA	0.75	Appendix I
1000	Converts Btu to kBtu	Appendix I
ηCool	11	Appendix I
HDD	1911	Appendix I
ηHeat	1	Appendix I
ADJ_{Floor}	88%	Appendix I
F_e	3.14%	Appendix I
29.3	kWh per therm	Appendix I
CF	0.000466080	Appendix I
ηHeat gas	71%	Appendix I

Floor Insulation	Verified Inputs	Verified Source
100,000	Converts Btu to therms	Appendix I

Lighting Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program lighting measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations and input parameters are described in the Energy Efficiency Kits section, and input values specific to SF LI lighting measures are described in the tables below.

Table 68. Wattage Table for SF LI Lighting Measures

Input	Watts EE	Watts Base
LED - 10W (Halogen baseline) LIDI	9.1	41.3
LED - 12W Dimmable Light Bulb (Replacing Specialty Incandescent) LI DI	11.0	53.0
LED - 15W (Halogen baseline) LIDI	10.6	53.0
LED - 15W Flood Light PAR30 Bulb (Halogen baseline) LI DI	14.0	55.0
LED - 18W Flood Light PAR38 Bulb (Halogen baseline) LI DI	17.0	70.0
LED - 20W (Halogen baseline) LIDI	15.0	72.0
LED - 4W Candelabra (Replacing Specialty Incandescent) LI DI	4.5	40.4
LED - 4W Candelabra (CFL baseline) LIDI	4.5	9.0

Table 69. Lighting Input Values for SF LI Lighting Measures

Input	Single Family and Mobile Home Channels		Community Grants Channel	
	Value	Source	Value	Source
ISR	100%	PY2019 Participant Survey	87.95%	PY2019 Participant Survey(Value for LEDs delivered through the RAR Program Kits)
Hours Res	674.18	Appendix F	674.18	Appendix F
WHF	0.99	Appendix F	0.99	Appendix F
Coincidence Factor (CF)	0.0001492529	Appendix F	0.0001492529	Appendix F
%Res	100%	Appendix F	100%	Appendix F

Input	Single Family and Mobile Home Channels		Community Grants Channel	
	Value	Source	Value	Source
Leakage	0%	Appendix F	0%	Appendix F

Low Flow Aerator Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program low flow aerator measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations input parameters are described in the Energy Efficiency Kits section, and input values specific to SF LI low flow aerator measures are described in the table below.

Table 70. Faucet Aerator Input Values for SF LI Measures

Input	Bathroom Aerator	Kitchen Aerator	Source
%ElectricDHW	1 for Electric DHW and Unknown; 0 for non-electric DHW	1 for Electric DHW and Unknown; 0 for non-electric DHW	Appendix F
GPM_base	2.2	2.2	Appendix F
L_base	1.6	3.7	Appendix F
GPM_low	1.5	1.5	Appendix F
L_low	1.6	3.7	Appendix F
Household	2.07	2.07	Appendix F
DF	0.9	0.75	Appendix F
FPH	1.4	1.0	Appendix F
EPG_electric	0.0615	0.0790	Appendix F
ISR	89% for SF & MH Channels 57% for Grants Channel	89% for SF & MH Channels 51% for Grants Channel	PY2019 Survey for SF & MH Channels; Appendix F value for EE Kits for Grants Channel
Coincidence Factor (CF)	0.0000887318	0.00008873118	Appendix F

Low Flow Showerhead Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program low flow showerhead measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations input parameters are described in the Energy Efficiency Kits section, and input values specific to SF LI low flow showerhead measures are described in the table below.

Table 71. Low Flow Shower Head Input Values for SF LI Measures

Input	Value	Source
%ElectricDHW	1 for Electric/Unknown DHW; 0 for non-electric DHW	Appendix F
GPM_base	2.2	Appendix F
L_base	8.66	Appendix F
GPM_low	1.5	Appendix F
L_low	8.66	Appendix F
Household	2.67	Appendix F
SPCD	0.66	Appendix F
SPH	2.050	Appendix F
EPG_electric	0.1087	Appendix F
ISR	89% for SF & MH Channels 58.5% for Grants Channel	PY2019 for SF & MH Channels; Appendix F value for EE Kits for Grants Channel
Coincidence Factor (CF)	0.0000887318	Appendix F

Pipe Insulation Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program pipe insulation measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations input parameters are described in the Energy Efficiency Kits section, and input values specific to SF LI pipe insulation measures are described in the table below.

Table 72. Pipe Insulation Input Values for SF LI Measures

Input	Value	Source
Cbase	0.144	Appendix F

Input	Value	Source
Rbase	1.000	Appendix F
CEE	0.406	Appendix F
REE	3.600	Appendix F
L	1	Appendix F
ΔT	58.90	Appendix F
Hours	8,766	Appendix F
ηDHW_{Elec}	0.98	Appendix F
Coincidence Factor (CF)	0.0000887318	Appendix F
ISR	0.96	Appendix F

Refrigerator Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program refrigerator measures, the evaluation team used a deemed savings value from the November 2019 Ameren Missouri Appendix F.

$$\Delta kWh = 564.66$$

$$\Delta kW = \Delta kWh \times 0.0001286107$$

Room Air Conditioner (Room AC) Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low-Income Program Room AC measures, the evaluation team used a deemed savings value from the November 2019 Ameren Missouri Appendix F.

$$\Delta kWh = 76.92$$

$$\Delta kW = \Delta kWh \times 0.0009474181$$

Tier 2 Advanced Power Strips Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Single Family Low -ncome Program Tier 2 advanced power strip measures, the evaluation team applied the November 2019 Ameren Missouri TRM and Appendix F deemed savings tables to the program tracking database.

The savings equations, input parameters, and input values are described in the Energy Efficient Products section.

Multifamily Low Income (MF LI)

Gross Impact Methodology

AC Tune-Up Savings Assumptions

To determine verified gross energy and demand savings for PY2019 Residential Multifamily Low-Income Program AC Tune-Up measures, the evaluation team used the Appendix F deemed savings tables.

The team used the following values for electric energy and demand savings:

Equation 62. AC Tune-Up (no charge or coil clean) Deemed Energy and Demand Savings

$$kWh = 142.5$$

$$kW = 0.1350$$

Ceiling Insulation Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 ceiling insulation measures, the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 63. Ceiling Insulation Energy and Demand Savings Equations

$$kWh = kWh_{Cooling} + kWh_{Heating}$$

$$kWh_{Cooling} = \frac{\left(\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) \times A_{Attic} \times (1 - FramingFactor_{Attic} \times CDD \times 24 \times DUA\right)}{1000 \times \eta Cool}$$

$$kWh_{Heating} = \frac{\left(\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) \times A_{Attic} \times (1 - FramingFactor_{Attic} \times HDD \times 24 \times ADJAttic\right)}{\eta Heat \times 3412}$$

$$kW = kWh_{Cooling} \times CF$$

Where:

Ceiling Insulation	Verified Inputs	Verified Source
R_old	Custom	Tracking Data
R_attic	Custom	Tracking Data
A_attic	Custom	Tracking Data
FramingFactor_Attic	7%	Appendix I
CDD	1646	Appendix I
DUA	0.75	Appendix I
nCool	Custom	Tracking Data
HDD	4,486	Appendix I
ADJ_Attic	0.74	Appendix I
nHeat	Custom	Tracking Data: HSPF * 0.85 /3.412
CF	0.00095	Appendix I

Ductless AC Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Low-Income ductless AC measures, the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 64. Ductless AC Energy and Demand Savings Equations

$$kWh = kWh_{heat} + kWh_{cool}$$

$$kWh_{heat} = (Capacity_{heat} \times EFLH_{heat} \times (\frac{1}{HSPF_{exist}} - \frac{1}{HSPF_{ee}})) \, / \, 1000) \times HF$$

$$kWh_{cool} = (Capacity_{cool} \times EFLH_{cool} \times (\frac{1}{SEER_{exist}} - \frac{1}{SEER_{ee}})) \, / \, 1000) \times HF$$

$$kW = kWh_{Cooling} \times CF$$

Ductless AC	Verified Inputs	Verified Source
Capacity_heat	Custom	Tracking Data
EFLH_heat	1,034	Appendix I
HSPF_exist	Custom. 3.41 when not provided.	Tracking Data
HSPF_ee	11.32	Ameren Deemed Savings Table_PDF.xlsx
Capacity_cool	Custom. 24,00 when not provided.	Tracking Data
EFLH_cool	635	Appendix I
SEER_exist	Custom. 8 when not provided.	Tracking Data
SEER_ee	Custom 18 when not provided.	Tracking Data
HF	0.65	Appendix I
CF	0.000947418	Appendix I

Lighting Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Low-Income lighting measures, the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

Enduses were improperly reported and did not consistently match the Measure Description. For example, AC Tune-up measures were categorized as Water heating, Lighting, Cooling, and HeatCool. For reporting, the evaluation team mapped each Measure Description to an enduse.

Table 73. PY2019 Multifamily Market Rate Evaluation Remapping

Measure	Enduse
AC Tune-up / Refrigerant charge-Multifamily Low-Income-V2	HVAC RES
Ceiling Insulation-Multifamily Low-Income	Building Shell RES
Common Areas Business Custom Measure Ext Lighting BUS	Lighting BUS
Common Areas Business Custom Measure HVAC BUS	Lighting BUS
Directional LED-MFIE	Lighting BUS
Ductless AC-Multifamily Low-Income	HVAC RES
Exit Sign-MFIE	Lighting BUS
Kitchen Aerator-MFIE	Water Heating Res
Learning Thermostat MIFE	HVAC BUS
LED - 10W (CFL baseline) LIDI-Multifamily Low-Income	Lighting RES
LED - 10W (Halogen baseline) LIDI-Multifamily Low-Income-V2	Lighting RES
LED Fixture-MFIE	EXT Lighting BUS
Low Flow Bathroom Faucet Aerator MFLI DI-Multifamily Low-Income-V2	Water Heating Res
Low Flow Showerhead MFLI DI-Multifamily Low-Income	Water Heating Res

Measure	Enduse
Low Flow Showerhead MFLI DI-Multifamily Low-Income-V2	Water Heating Res
Omnidirectional LED-MFIE	Lighting BUS
TLED-MFIE	Lighting BUS

The team used the following equations to calculate electric energy and demand savings:

Equation 65. Lighting Energy and Demand Savings Equations

$$kWh = (Watts_{Base} - Watt_{EE}) \times ISR \times (1 - LKG) \times (Hours \times WHF)/1{,}000$$

$$kW = kWh \times CF$$

Lighting	Enduse	Verified Inputs	Verified Source
WattsBase	EXT Lighting BUS	Custom	Tracking Data
	Lighting BUS	Custom	Tracking Data
	Lighting Res	Custom. If not provided, Ameren calculator value is used (41.32 W).	Tracking Data, MFLI Deemed Table in "Ameren Deemed Savings Table_PDF.xlsx"
WattsEE	EXT Lighting BUS	Custom	Tracking Data
	Lighting BUS	Custom	Tracking Data
	Lighting Res	Custom. If not provided, Ameren calculator value is used (7 W).	Tracking Data, MFLI Deemed Table in "Ameren Deemed Savings Table_PDF.xlsx"
ISR	EXT Lighting BUS	0.987	Appendix I
	Lighting BUS	0.987	Appendix I
	Lighting Res	0.9818	Appendix I
Hours	EXT Lighting BUS	2,876	Appendix H for Midrise Apartment - Building
	Lighting BUS	8,766 (exit sign), 2,876 (others)	Appendix H for Exit Signs. Appendix H for Midrise Apartment – Building.
	Lighting Res	728	Appendix I
WHF	EXT Lighting BUS	1	Appendix I
	Lighting BUS	1.14	Appendix H
	Lighting Res	0.88	Appendix I
CF	EXT Lighting BUS	0.0000056	Appendix I - CF for nonresidential. No CF provided in TRM for exterior.
	Lighting BUS	0.0001900	Appendix I - CF for nonresidential.
	Lighting Res	0.0001493	Appendix I

Hot Water Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Low-Income hot water measures (aerators, showerheads), the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 66. Low Flow Faucet Aerator Energy and Demand Savings Equations

$$kWh = \%ElectricDHW \times ((GPM_{base} \times L_{base} - GPM_{low}) \times Household \times 365.25 \times \frac{DF}{FPH}) \times EPG_{electric} \times ISR$$

$$kW = kWh \times CF$$

Bathroom Faucet Aerator	Verified Inputs	Verified Source
%ElectricDHW	1	Appendix I
GPM_base	2.2	Preliminary Data measure description
L_base	1.6	Appendix I
GPM_low	0.5	Tracking Data
L_low	1.6	Appendix I
Household	1.56	Appendix I
DF	0.9	Appendix I
FPH	1.86	Appendix I
EPG_electric	0.061532825	Appendix I
ISR	0.95	Appendix I
CF	8.873E-05	Appendix I

Kitchen Faucet Aerator	Verified Inputs	Verified Source
%ElectricDHW	1	Appendix I
GPM_base	2.2	Preliminary Data measure description (used bathroom aerator baseline, no kitchen aerator baseline was provided in preliminary data)
L_base	4.5	Appendix I
GPM_low	1.5	Tracking Data
L_low	4.5	Appendix I
Household	1.56	Appendix I
DF	0.75	Appendix I
FPH	1.19	Appendix I
EPG_electric	0.078971278	Appendix I
ISR	1	Appendix I
CF	8.873E-05	Appendix I

Equation 67. Low Flow Faucet Aerator Energy and Demand Savings Equations

$$kWh = \%ElectricDHW \times ((GPM_{base} \times L_{base} - GPM_{low}) \times Household \times 365.25 \times \frac{SPCD}{SPH}) \times EPG_{electric} \times ISR$$

$$kW = kWh \times CF$$

Low Flow Showerhead	Verified Inputs	Verified Source
%ElectricDHW	1	Appendix I
GPM_base	2.5	Preliminary Data measure description
L_base	7.8	Appendix I
GPM_low	1.25	Tracking Data
L_low	7.8	Appendix I
Household	1.52	Appendix I
SPCD	0.6	Appendix I
FPH	1	Appendix I
EPG_electric	0.1	Appendix I
ISR	1	Appendix I
CF	8.873E-05	Appendix I

Learning Thermostat Savings Assumptions

To calculate verified gross energy and demand savings for PY2019 Multifamily Low-Income learning thermostat measures, the evaluation team applied the PY2019 Ameren Missouri TRM Appendix I to the program tracking database.

The team used the following equations to calculate electric energy and demand savings:

Equation 68. Learning Thermostat Energy and Demand Savings Equations

$$kWh = kWh_{Heating} + kWh_{Cooling}$$

$$kWh_{Heating} = \%ElectricHeat \times HeatingConsumption_{Electric} \times HF \times HeatingReduction \times ISR + (\Delta Therms \times Fe \times 29.3)$$

$$kWh_{Cooling} = \%AC \times \left(\frac{EFLH_{Cool} \times CapacityCool \times \frac{1}{SEER}}{1000} \right) \times CoolingReduction \times ISR$$

$$\Delta Therms = \%FossilHeat \times HeatingConsumption_{Gas} \times HF \times HeatingReduction \times ISR$$

$$kW = kWh_{Cooling} \times CF$$

Where:

Learning Thermostat	Verified Inputs	Verified Source
%ElectricHeat	1	Appendix I
HeatingConsumption_Electric	11,456	Appendix I
HF	0.65	Appendix I
HeatingReduction	0.088	Tracking Data (assumes Manual replacement)
Eff_ISR	1	Appendix I
deltaTherm	0	Assume electric heating
%AC	1	Assume AC present
EFLH_cool	869	Appendix I
Capacity_cool	24,000	Tracking Data
SEER	8	Tracking Data
CoolingReduction	0.08	Appendix I
CF	0.000947418	Appendix I

Non-Participant Spillover Methods and Results

This appendix provides an overview of the methods the evaluation team used to develop non-participant spillover (NPSO) for PY2019 Ameren Missouri residential programs. This appendix begins with a methods overview and then discusses the results and NPSO calculation.

Definition of NPSO

Ameren Missouri has been running energy efficiency programs for many years. A key component of the residential portfolio has been the marketing and outreach campaign to promote the programs and general energy-efficiency awareness among customers. Sustained utility program and general marketing can affect customers' perceptions of their energy usage, and, in some cases, motivate them to take efficiency actions outside of the utility's program. We define NPSO as the energy savings that Ameren Missouri's program marketing activities caused but did not rebate.

Methods

In this section, we describe the data sources for the analysis, the rationale for measures and programs eligible for NPSO, and the qualification criteria for a measure to count towards NPSO savings.

Data Sources

The NPSO analysis uses data we collected through a residential general population survey of a random sample of 4,804[15] Ameren Missouri residential customers. After completing the survey, we matched survey respondents' account numbers to those of all PY2019 program participants and excluded residential program participants from the analysis.[16] We removed program participants for all residential programs except upstream Residential Lighting and Multifamily (low-income and market-rate). Upstream Residential Lighting data does not contain customer-specific information due to its design and the Multifamily program tracking data does not contain the tenant information necessary to identify program participants. We considered customers who were part of the legacy and 2019 Home Energy Report (HER) treatment groups as participants and dropped them from the analysis. After removing 1,354 confirmed program participants, we were left with 3,450 non-participant respondents for analysis.

Eligible Measures

NPSO savings are limited to measure installations that (1) the Ameren Missouri residential program portfolio supports (i.e. "like" measures), (2) could be theoretically due to Ameren Missouri's promotional efforts, and

[15] 4,755 respondents completed the entire survey. We added 49 partial completes for this analysis because they completed the entire NPSO question battery, bringing the total to 4,804.

[16] We removed participant respondents after survey fielding instead of during sample development or survey fielding through screening questions for several reasons: (1) The survey served multiple purposes. In addition to using results to estimate NPSO, the survey contained questions to support program process evaluations and market studies. We needed to ask these additional questions of the entire residential customer base to have representative and usable results; (2) At the time of the survey fielding, we did not have a complete list of all PY2019 participants; (3) Previous NPSO surveys for Ameren Missouri suggest customers overreport their participation in Ameren Missouri programs.

(3) are not the focus of NPSO estimation through specific program evaluations. Table 74 lists the eligible measures and their associated programs.

Table 74. PY2019 NPSO Eligible Measures

Measure	Program
Kitchen faucet aerator	Energy Efficient Kits, Appliance Recycling
Bathroom faucet aerator	Energy Efficient Kits, Appliance Recycling
Low flow showerhead	Energy Efficient Kits, Appliance Recycling
Hot water pipe insulation	Energy Efficient Kits, Appliance Recycling
Central air conditioner (CAC)	HVAC
Air source heat pump (ASHP)	HVAC
Ground source heat pump (GSHP) [a]	HVAC
Ductless/Minisplit Heat Pump (DMSHP)	HVAC
Furnace fan with electronic commutating motor (ECM)	HVAC
Advanced (i.e., learning or smart) thermostat	Energy Efficient Products, HVAC
Advanced power strips [a]	Energy Efficient Products
Pool pump	Energy Efficient Products
Heat pump water heater (HPWH)	Energy Efficient Products
Recycled refrigerator	Appliance Recycling
Recycled freezer	Appliance Recycling

[a] While we asked about advanced power strips and ground-source heat pumps in the survey as potential NPSO-eligible measure, we ultimately decided to remove them from NPSO eligibility. Please refer to the NPSO Results section later in this appendix for more detail.

Low-Income Measures: We have excluded measures that are only available through low-income programs such as insulation and AC tune-ups due to the program theory and marketing activities associated with low-income programs. Program marketing of low-income programs is targeted to low-income customers and does not promote specific measures to the wider Ameren Missouri customer base. In addition, we assume that low-income customers would not take program-supported actions without program support and assign those programs a net-to-gross ratio of 1.0. Therefore, we assume that non-participating low-income customers who have learned of the program but did not participate will not purchase and install the low-income program measures on their own.

Other NPSO Evaluations: To avoid double counting savings, we excluded LEDs because we estimated NPSO for lighting measures through the in-store customer intercepts that are part of the Residential Lighting Program evaluation. We include HVAC measures in the NPSO survey but asked additional survey questions to avoid double counting savings. The HVAC Program evaluation included an estimation of NPSO through participating contractors. To avoid double counting savings, we asked all respondents who installed a new energy efficient HVAC unit for the name of their contractor and excluded any installations performed by participating contractors. This will restrict NPSO savings from this survey to installations performed by non-participating contractors.

Programs Eligible for NPSO

We produced a total estimate of NPSO from the measures in Table 74 and divided the savings between the four programs listed in Table 75 based on the relative size of each program's ex-post gross savings.. These programs had marketing campaigns that could theoretically produce NPSO and will not receive NPSO from the Residential Lighting evaluation. We exclude the HER and Peak Time Savings programs because the program design and associated theory of influence will not result in NPSO (i.e. the HER program only provides information to treated participants, and the Peak Time Savings Program does not promote event days to non-participants encouraging them to reduce load voluntarily).

Table 75. Residential Programs Eligible for NPSO Savings

Program
HVAC
Energy Efficient Products
Appliance Recycling
Energy Efficient Kits

Initial NPSO Screening Criteria

To determine if a survey respondent installed an *NPSO-eligible* measure, the survey asked respondents if they installed an energy efficient version of the measures listed in Table 74 since March 1, 2019, the beginning of the program year. We asked several follow-up questions of survey respondents who said they completed an NPSO-eligible measure to determine if those measures should count towards NPSO savings and are thus *NPSO-qualified*. In this Appendix, we use the term *NPSO-eligible* to refer to like-program measures that could count as NPSO, and *NPSO-qualified* measures to refer to NPSO-eligible measures that an individual respondent took that passed the screening criteria and count towards NPSO savings.

The scoring algorithms in this section identify the question numbers, as well as the proposed scoring for each response option. Please refer to the accompanying survey instrument for the full text and response options of each survey question. To qualify as NPSO, a respondent needed to meet the following criteria:

a. Aware that Ameren Missouri provides rebates or discounts on energy efficiency equipment or aware of at least one specific program.

b. At least one element of Ameren Missouri's program marketing and outreach motivated the respondent to adopt the measure.

c. The respondent had a valid reason for considering the measure to be energy efficient.

d. Though aware of Ameren Missouri rebates or programs, the respondent had a valid reason for not applying for an Ameren Missouri rebate/participating.

e. The respondent had a valid energy saving reason for installing the measure.

f. The measure generates electric savings (thermostats or water measures that could also generate gas savings)

g. For recycled appliances, the appliance was removed from the electric grid.

The six diagrams below provide the associated survey question text and response scoring criteria for each criteria.

Figure 18. NPSO Criterion A Flowchart

Criterion A: Aware that Ameren Missouri provides rebates or discounts on energy efficiency equipment or awareness of at least one specific program.

Q4. Are you aware that Ameren Missouri sponsors energy efficiency programs that provide rebates and discounts for energy-saving equipment and home improvements?

Q5. Are you familiar with the following the energy efficiency programs that were sponsored by Ameren Missouri during 2019?

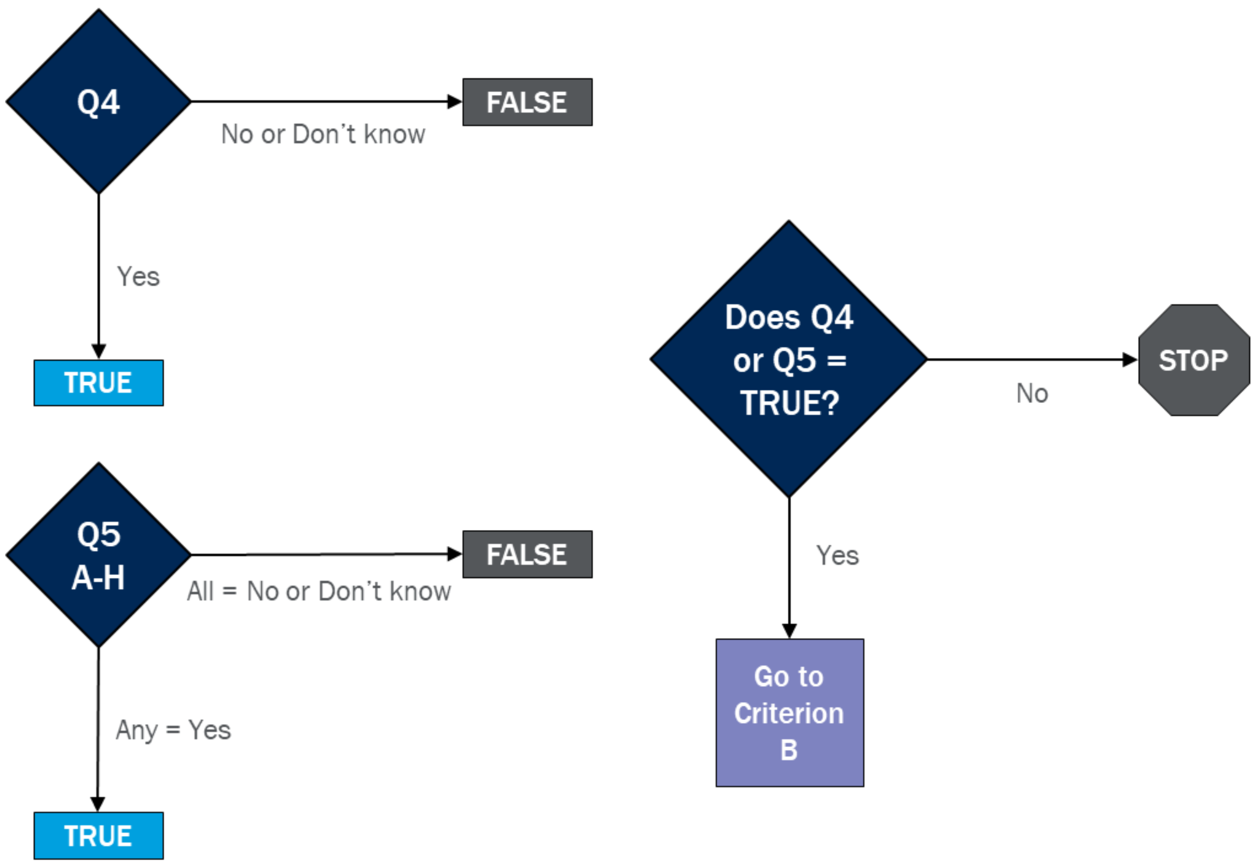


Figure 19. NPSO Criterion B Flowchart

Criterion B: At least one element of Ameren Missouri's program marketing and outreach motivated the respondent to adopt the measure

Q44. How important was each of the following elements in your decision to purchase and install the measure? [USE SCALE: 1. Very Important 2. Somewhat important 3. A little important 4. Not at all important 97. Does not apply 98. Don't know]

A. Information about energy savings from Ameren Missouri's marketing or bill insert
B. Ameren Missouri's marketing information from a contractor or retailer
C. Information from family, friends, or colleagues who installed energy efficient equipment and received a rebate from Ameren Missouri
D. Participation in an Ameren Missouri energy efficiency program **prior to 2019**

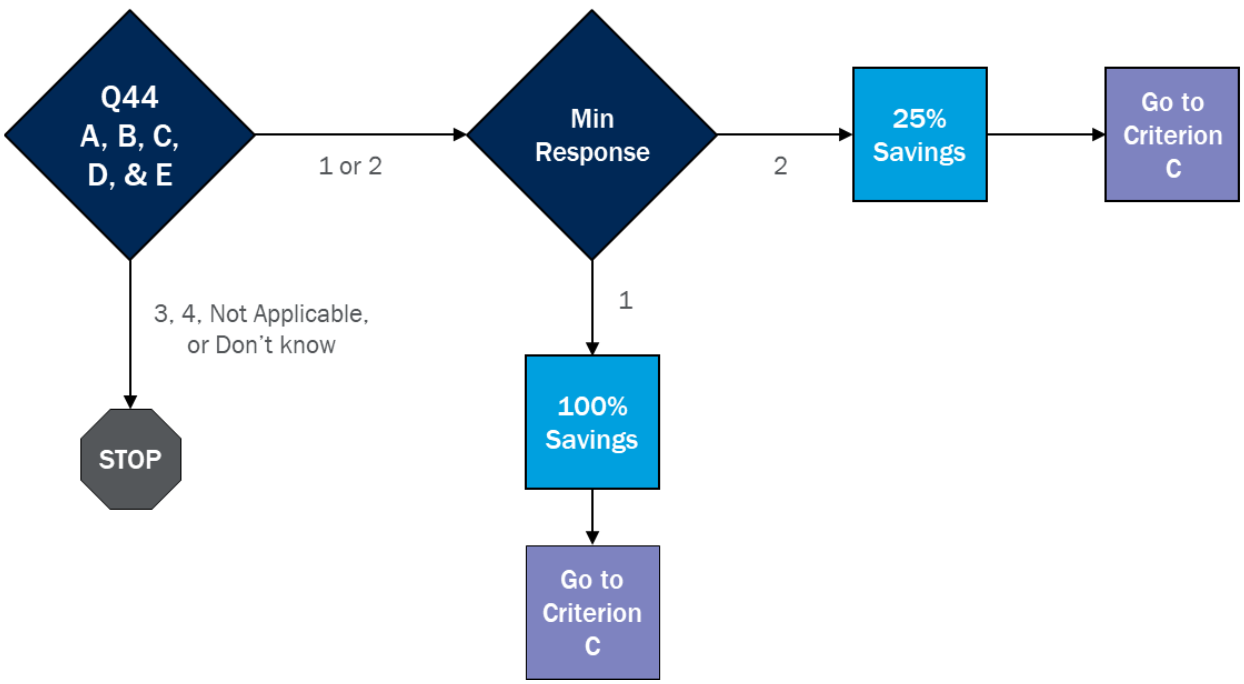
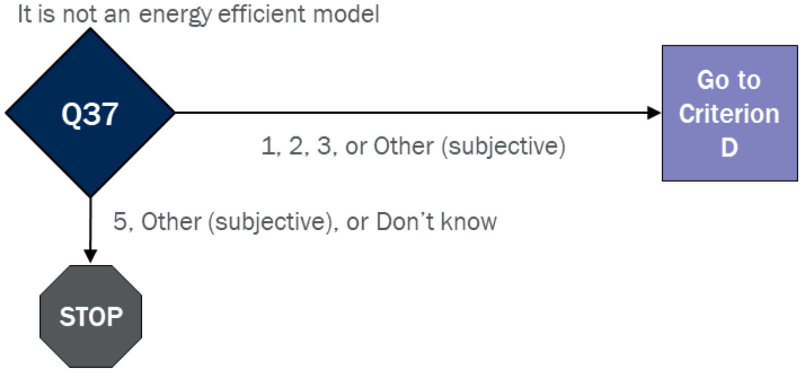


Figure 20. NPSO Criterion C and D Flowchart

Criterion C: The respondent had a valid reason for considering the adopted measure to be energy efficient.

Q37. How do you know the measure is energy efficient?

1. It's ENERGY STAR certified
2. The retailer/dealer/contractor told me it was energy efficient
3. Information about the product from packaging, websites, etc. indicate it was energy efficient
4. Other (please specify)
5. It is not an energy efficient model



Criterion D: Though aware of Ameren Missouri rebates or programs, the respondent had a valid reason for not applying for an Ameren Missouri rebate/participating.

Q41. Why didn't you or your contractor apply for a rebate through Ameren Missouri for the measure?

1. I'm still planning to apply for an Ameren Missouri rebate
2. It was confusing
3. I forgot about it
4. I did not know the equipment qualified for a rebate
5. I wanted a different model that did not qualify for a rebate
6. I applied for a rebate but did not receive one
7. My contractor/retailer does not participate in Ameren Missouri programs
8. Other (please specify)

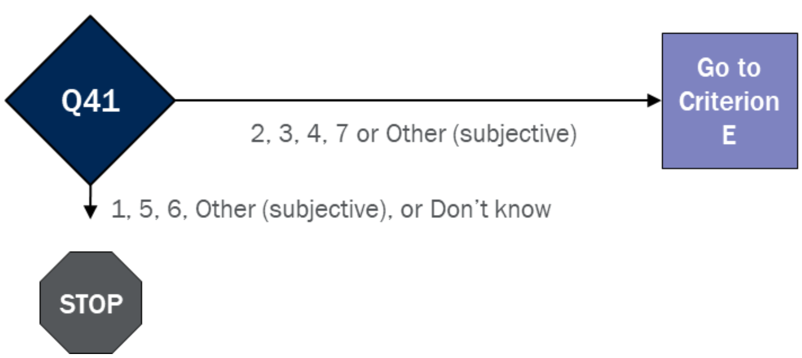


Figure 21. NPSO Criterion E Flowchart

Criterion E: The respondent had a valid energy saving reason for deciding to install the measure.

Q38. Which one of the following reasons best describes why you decided to install a measure?

1. To save energy
2. To save money
3. To replace failing equipment
4. Needed to replace anyway
5. Liked the style
6. Was ready to update
7. To improve comfort
8. Other (please specify)

Q39. Which one of the following reasons best describes why you chose an energy efficient model of a measure?

1. To save money
2. To save energy
3. Like the style
4. It had other features I liked
5. It was the cheapest product available
6. It was the only option available
7. Other (please specify)

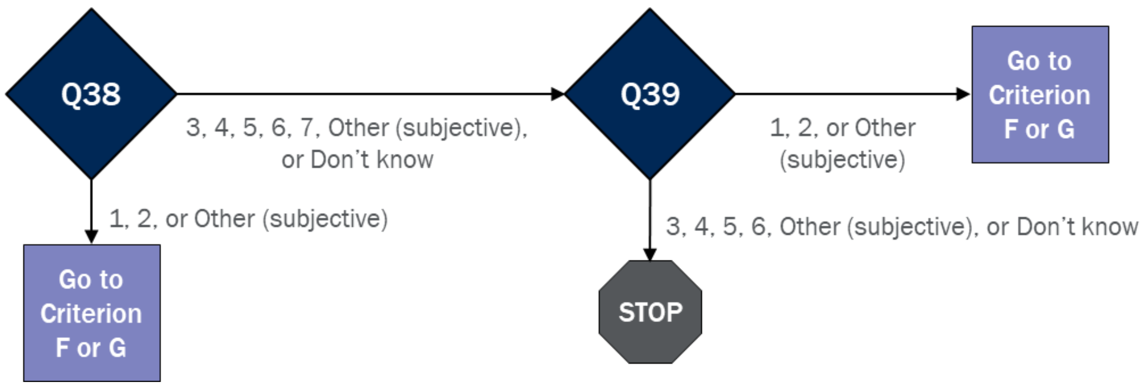


Figure 22. NPSO Criterion F Flowchart

Criterion F: [For smart thermostats and water measures] The adopted measure generated electric savings.

Q15. What type of <u>cooling equipment</u> do you have in your home?

Q19. What is the primary type of <u>heating equipment</u> in your home?

Q24. Does your <u>water heater</u> use electricity, natural gas, or something else?

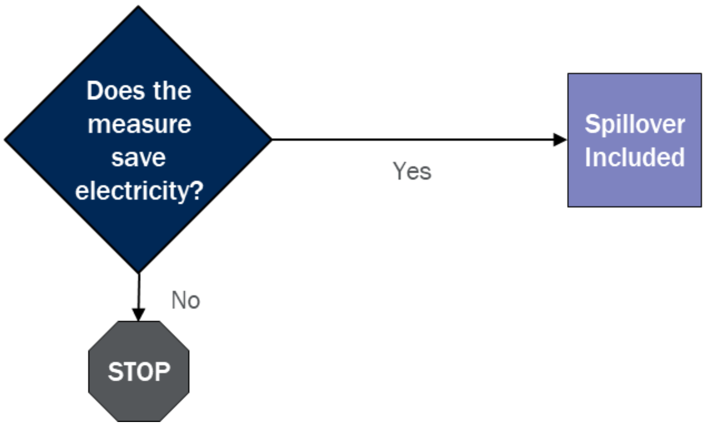


Figure 23. NPSO Criterion G Flowchart

Criterion G: [For recycled appliances] The appliance was removed from the grid

Q48/49. How did you get rid of your working refrigerator/freezer?

1. Sold or gave it to person, business, or charity that planned to use it
2. Purchased a new refrigerator/freezer and the retailer took the old working refrigerator/freezer
3. Took it to a landfill or recycling center
4. Hired a garbage collector or recycle center to take it
5. An Ameren Missouri contractor took it
6. Other (please specify)

98. Don't know

Post-Screening Adjustments

After the dropping respondents whose NPSO-eligible actions did not pass the screening criteria, we performed five additional types of post-screening adjustments. These adjustments included: (1) removing select measures from consideration for NPSO savings; (2) reviewing open-ended "other" survey responses to classify the response in terms of the screening criteria; (3) phone verification of questionable measure quantities; (4) removing any respondents who had their new HVAC systems installed by a participating contractor or who could not confirm their contractor; and (5) adjusting the counts of NPSO-eligible measures that were distributed as part of school kits to avoid double counting savings. We provide more detail about these screening adjustments in the NPSO Results section.

NPSO Calculation

Once we determined the final list of NPSO measures, we determined whether each respondent should receive full or partial credit for their measures based on Criterion B (see Figure 19). We then determined average savings per measure using deemed savings values from the Ameren Missouri Technical Reference Manual (TRM), or in some cases the average of several deemed savings values we used in the 2019 program evaluations (see Table 76 for more detail). We determined the total NPSO savings among surveyed non-participants by applying the adjusted measure quantities to the average savings values for each measure. We determined the total NPSO among Ameren Missouri non-participants by extrapolating the average savings among non-participants (n=3,450) to the population of Ameren Missouri non-participants (N=637,968). The last step was to allocate NPSO to each program based on the relative size of its ex-post gross savings.

Table 76. Average Savings Value Sources

Measure	Average kWh Savings per Measure	Average kW Savings per Measure	Source
HPWH	2,507	0.20376	Deemed savings value from the Ameren Missouri TRM.
Pool pump	2,050	0.48291	Average from the Energy Efficient Products Program evaluation. There were two measure types: ▪ ENERGY STAR variable frequency drives (VFDs) on Residential Swimming Pool Pumps ▪ ENERGY STAR Pool Pump and motor w auto controls - multi speed
Recycled refrigerator	858	0.11093	Weighted average of pre-1990 and post-1990 measures from the Appliance Recycling Program evaluation, based on the Ameren Missouri TRM.
Recycled freezer	776	0.09717	Weighted average of pre-1990 and post-1990 measures from the Appliance Recycling Program evaluation, based on the Ameren Missouri TRM.
Furnace Fan with ECM	585	0.27266	Average savings values from the HVAC Program evaluation for replace-on-burnout measures, based on the Ameren Missouri TRM.
CAC	493	0.46673	Average savings values from the HVAC Program evaluation for replace-on-burnout measures, based on the Ameren Missouri TRM.

Measure	Average kWh Savings per Measure	Average kW Savings per Measure	Source
Advanced thermostat	450	0.17646	Combined average savings values from the Energy Efficient Products (453 kWh) and HVAC program evaluations (447 kWh). Note, both programs used multiple deemed savings values from the Ameren Missouri TRM based on heating and cooling equipment type.
Low-flow showerhead	71.66	0.00636	Deemed savings value from the Ameren Missouri TRM
Hot water pipe insulation	2.53 per foot, 37 on average per respondent.	0.00022 per foot, 0.00330 on average per respondent	We applied the deemed savings value per foot (2.53 kWh) from the Ameren Missouri TRM to the total feet installed by qualifying respondents. We then divided the total savings by the total qualifying respondents to arrive at an average per respondent.
Kitchen faucet aerator	29.75	0.00264	Deemed savings value from the Ameren Missouri TRM
Bathroom faucet aerator	6.17	0.00055	Deemed savings value from the Ameren Missouri TRM

Note: This table excludes measure types that ultimately did not qualify for NPSO, including GSHPs, ASHPs, DMSHPs, and advanced power strips.

NPSO Results

The section below describes the results of initial data cleaning (i.e., removing program participants), the survey response screening results, and additional post-screening adjustments we made before finalizing results. We then present the final NPSO results and the program-specific allocations.

Initial Data Cleaning

We identified 1,354 residential energy efficiency program participants among respondents (28%, n=4,804). Among participants, the vast majority (96%, n=1,354) participated in one program, while 58 participated in two programs and one participated in three programs. HER was by far the most common program among respondents, followed by HVAC. Table 77 shows the total participants among respondents compared to the total program participants for each program.

Table 77. Ameren Missouri Program Participation Among Respondents (n=1,354)

Ameren Missouri Residential Program	Number of Participants Among Respondents	Number of Unique Program Participant in 2019 (Program Tracking Data)
Home Energy Reports	1,235	282,887
Residential HVAC	97	11,024
Efficient Products	53	6,685
Appliance Recycling	15	1,864
Lighting Online Store	8	737
Low-Income Program	5	491

The remaining 3,450 respondents were non-participants who could potentially have completed NPSO-eligible measures (an NPSO-eligible measure is a measure from Table 74). Among them, 802 installed one of the 13 eligible NPSO measures and 271 recycled an appliance for a total of 981 respondents who had at least one NPSO-eligible measure, which is 28% of the non-participant population (n=3,450). However, most of these measures ultimately did not qualify for NPSO. In the next two sections we present the results of the initial screening using survey responses to identify NPSO qualified measures, using Criteria A through G presented earlier (Figure 18 through Figure 23). Note, we used different screening methods for installed measures and recycled appliances and, as such, we present the screening results separately below.

Initial Screening Results – Installed Measures

We started with 4,804 respondents who installed 2,437 NPSO-eligible measures. We dropped 1,354 respondents who were program participants and then dropped an additional 2,648 respondents because they did not install one of 13 NPSO-eligible measures (excluding appliance recycling). We began the analysis with 802 non-participants who installed 1,611 NPSO-eligible measures. After executing Criteria A through F (note: Criterion G is specific to appliance recycling), 131 respondents and 246 potential NPSO-eligible measures passed screening and remained for further analysis. Table 78 summarizes these steps and more detail follows the table.

Table 78. NPSO Screening Summary (Installed Measures)

Drop Reason	Number of Respondents Dropped	Total Respondents Remaining	Total NPSO-Eligible Measures Remaining
Original count	-	4,804	2,437
Respondent appeared in program tracking data	1,354	3,450	1,611
No eligible measure completed	2,648	802	1,611
Unaware of Ameren Missouri's support for energy efficiency or programs (Criterion A)	86	716	1,456
Not influenced by Ameren Missouri's marketing or program participation *prior to 2019* (Criteria B)	300	416	915
Did not pass initial screen for Criteria C-F	285	131	246
Candidate Pool for Further Analysis	-	**131**	**246**

Criterion A: Among those who installed NPSO-eligible measures (n=802), most were aware of a specific residential program (85%). A few (13%) were unaware of a specific program but were still generally aware that Ameren Missouri supports rebates or discounts on energy efficiency equipment. These respondents (716 total) passed Criterion A for NPSO. We dropped the remaining 86 respondents (who were not aware of a specific program or generally of Ameren Missouri's support for energy efficiency).

Table 79. Criterion A Screening Results (Installed Measures)

Generally Aware of Ameren Missouri's Support of Energy Efficiency	Aware of a Specific Ameren Missouri Program		Total
	Yes	No	
Yes	580	31	**611**
No	105	86	**191**
Total	**685**	**117**	**802**

Note: We dropped the 86 respondents highlighted in green from the analysis.

Criterion B: Among the 716 who passed Criterion A, over half (416, 58%) reported that Ameren Missouri's marketing or their program participation prior to 2019 was "very important" or "somewhat important" in their decision to undertake an NPSO-eligible measure. Among the 416, all the information sources we tested were similarly important, on average. We dropped measures that were not influenced by these activities. We removed 300 respondents from the analysis and 541 total measures based on Criterion B. Table 80 summarizes responses to the Criterion B survey questions.

Table 80. Criterion B Screening Results (Installed Measures)

Information Source	Average Importance Score (Lower is More Important)	Number of Responses (Multiple Response and Excluding Invalid Responses) [a]
Information about energy savings from Ameren Missouri's marketing or bill insert	1.8	582
Ameren Missouri's marketing information from a contractor or retailer	2.0	515
Information from family, friends, or colleagues who installed energy efficient equipment and received a rebate from Ameren Missouri	2.1	487
Participation in an Ameren Missouri energy efficiency program prior to 2019	2.1	524

Note: Note: On a scale of 1-4 where 1 is "Very Important" and 4 is "Not at all Important"

[a] Average scores exclude "Don't know" and "Does not apply" responses. Number of responses exceed the total 416 respondents because some answered this question multiple times, for each measure they installed.

Criteria C through F: Next, we asked the 416 respondents who passed Criterion B about the topics below for each of their potential NPSO-eligible measures, where applicable.

- Criterion C. The respondent had a valid reason for considering the measure to be energy efficient.
- Criterion D. Though aware of Ameren Missouri rebates or programs, the respondent had a valid reason for not applying for an Ameren Missouri rebate/participating.
- Criterion E. The respondent had a valid energy saving reason for installing the measure.
- Criterion F. The measure generated electric savings (thermostats or water measures that could also generate gas savings)

- In the process of executing Criteria C-F, we identified 82 respondents (20%, n=416) who were not in the Ameren Missouri program participant lists (see Initial Data Cleaning) but reported that they received rebates from Ameren Missouri for at least one measure they installed. We also identified 27 respondents who said they received a rebate from another organization for at least one of their measures. Retailers and contractor companies were the most common “other” sources. We removed these measures from the analysis.

We removed 285 respondents and 623 measures from the analysis based on Criteria C – F. A total of 131 respondents and 246 installed measures passed the initial screen, representing 16% of the initial pool of respondents who installed a potential NPSO-eligible measure (n=802) and 15% of the initial pool of NPSO-eligible measures (n=1,611). Table 81 shows number of respondents and measures that passed the initial screen, by measure type.

Table 81. Respondents and Measures that Passed Initial Screening (Installed Measures)

NPSO-Eligible Installed Measure	Passed Initial Screen of Criteria A-F	
	Number of respondents	Number of Measures
Advanced power strip	30	71
CAC	26	26
Low-flow showerhead	21	24
Advanced thermostat	19	20
Kitchen faucet aerator	17	19
Bathroom faucet aerator	17	34
Hot water pipe insulation	14	14
Furnace Fan with ECM	11	12
Pool pump	8	8
HPWH	4	5
ASHP	3	3
GSHP	2	7
DMSHP	2	3
Total	**131**	**246**

Note: Total respondents does not sum across rows because respondents may have installed more than one measure.

Initial Screening Results – Recycled Appliances

We completed a similar screening analysis for recycled appliances. After removing program participants, we began the analysis with 271 non-participants who recycled an appliance (8%, n=3,450); 240 recycled a refrigerator and 77 recycled a freezer. We then executed Criteria A, B, and G. Criteria C – F were not applicable for recycled appliances. A total of 20 respondents who altogether recycled 13 refrigerators and nine freezers passed screening and remained for further analysis. Table 82 summarizes these steps and more detail follows the table.

Table 82. NPSO Screening Summary (Recycled Appliances)

Drop Reason	Number of Respondents Dropped	Total Respondents Remaining	Total Recycled Refrigerators Remaining	Total Recycled Freezers Remaining
Original Count	-	4,804	371	128
Respondent Was a Program Participant	1,354	3,450	240	77
Did not recycle an appliance	3,179	271	240	77
Unaware of Ameren MO's support for EE or programs (Criterion A)	48	223	200	63
May not have removed the appliance from the electric grid (Criterion G)	190	33	25	12
Not influenced by Ameren MO marketing or program participation *prior to 2019* (Criterion B)	13	20	13	9
Final NPSO Count (Recycled Appliances)	-	**20**	**13**	**9**

Note: In the survey, Criterion G questions proceeded the Criterion B questions for recycled appliances.

Criterion A: Among those who recycled an appliance (n=271), most were aware of a specific residential program (78%). A few (4%) were unaware of a program but were generally aware that Ameren Missouri supports rebates or discounts on energy efficiency equipment. These respondents (223 total) passed Criterion A for NPSO. We dropped the remaining 48 respondents from the analysis who were not aware of a specific program or generally of Ameren Missouri's support for energy efficiency.

Table 83. Criterion A Screening Results (Recycled Appliances)

Generally Aware of Ameren Missouri's Support of Energy Efficiency	Aware of a Specific Ameren Missouri Program		Total
	Yes	No	
Yes	168	11	179
No	44	48	92
Total	**212**	**59**	**271**

Note: We dropped the 48 respondents highlighted in green from the analysis.

Criterion G: Of the 223 remaining respondents, we asked survey questions to determine if they disposed of their appliance in a way that removed it from the grid. Less than one-fifth of them recycled refrigerators (25 of 200, 13%) and/or freezers (12 of 63, 19%) in a way that removed them from the grid. For instance, 79 respondents gave their old refrigerator to a business or friend who planned to use it. Another 71 purchased a new refrigerator and gave the old one to the retailer, which the retailer could resell. Table 84 (refrigerators) and Table 85 (freezers) show the results of the Criterion G screening questions.

Table 84. Criterion G Screening Results (Refrigerators)

Q48. How did you get rid of the working refrigerator?	Total
Sold or gave it to a person or a business that planned to use it	79
Purchased a new freezer and the retailer took the old working refrigerator	71
Took it to a landfill	14
Hired a garbage collector or recycle center to take it	11
An Ameren Missouri contractor took it	6

Other	15
Don't know	4
Total Respondents/Refrigerators	**200**

Note: We dropped the 175 respondents highlighted in green from the refrigerator analysis.

Table 85. Criterion G Screening Results (Freezers)

Q49. How did you get rid of the working freezer?	Total
Sold or gave it to a person or a business that planned to use it	22
Purchased a new freezer and the retailer took the old working refrigerator	19
Took it to a landfill	8
Hired a garbage collector or recycle center to take it	4
An Ameren Missouri contractor took it	1
Other	4
Don't know	5
Total Respondents/Refrigerators	**63**

Note: We dropped the 51 respondents/freezers highlighted in green from the freezer analysis.

Criterion B: Among the 25 remaining respondents who recycled a refrigerator, half of them (13, 52%) reported that Ameren Missouri's marketing or their program participation prior to 2019 was "very important" or "somewhat important" in their decision to undertake an NPSO-eligible measure. Among the 12 remaining respondents who recycled a freezer, nine (75%) reported that Ameren Missouri's marketing or their program participation prior to 2019 was "very important" or "somewhat important" in their decision. All the information sources we tested were similarly important, on average, and marketing directly from Ameren Missouri was the most important. Table 86 presents the results of the Criterion B screening questions.

Table 86. Criterion B Screening Results (Recycled Appliances)

Influence Factor	Average Importance Score (Lower is More Important)	
	Refrigerators	Freezers
Information about energy savings from Ameren Missouri's marketing or bill insert	2.3 (n=18)	1.8 (n=9)
Participation in an Ameren Missouri energy efficiency program prior to 2019	2.5 (n=17)	1.8 (n=9)
Information from family, friends, or colleagues who installed energy efficient equipment and received a rebate from Ameren Missouri	2.6 (n=15)	1.9 (n=7)
Ameren Missouri's marketing information from a contractor or retailer	2.6 (n=13)	2.1 (n=8)

Note: On a scale of 1-4 where 1 is "Very Important" and 4 is "Not at all Important". The base (n) varies because average scores exclude "Don't know" and "Does not apply" responses.

A total of 20 respondents who together recycled 13 refrigerators and nine freezers passed the initial screen, representing 8% of the initial pool of non-participants who recycled refrigerators (n=240) and 12% of the initial pool of non-participants who recycled freezers (n=77).

Analysis Pool After Screening

A total of 141 respondents, or 4% of non-participant respondents (n=3,450) passed the initial screening for NPSO-eligible installed measures or recycled appliances. These respondents installed 246 measures and/or recycled 22 appliances, for a total of 268 NPSO-eligible measures (15% of the initial pool, n=1,928[17]). Table 87 list the number of respondents and measures that passed the initial screen and proceeded to the next phase of the analysis.

Table 87. Potential NPSO Respondents and Measures Remaining After Initial Screening

NPSO-Eligible Measure	Passed Initial Screen of Criteria A-G	
	Number of respondents	Number of Measures
Installed Measures		
Advanced power strip	30	71
CAC	26	26
Low-flow showerhead	21	24
Advanced thermostat	19	20
Kitchen faucet aerator	17	19
Bathroom faucet aerator	17	34
Hot water pipe insulation	14	14
Furnace fan with ECM	11	12
Pool pump	8	8
HPWH	4	5
ASHP	3	3
GSHP	2	7
DMSHP	2	3
Installed measures subtotal	*131*	*246*
Recycled Appliances		
Recycled refrigerator	13	13
Recycled freezer	9	9
Total	**141**	**268**

Post-Screening Adjustments

The following sections describes the adjustments we made to eligible NPSO measures after the initial screening. Table 88 below summarizes the impact of each of these five adjustments. Based on these adjustments, we removed more than half of the NPSO-eligible measures that passed the initial screen (165 of 268, 62%) leaving 103 measures that qualified for NPSO savings (i.e., "NPSO-qualified measures").

Table 88. Summary of Post-Screening Adjustments

Drop Reason	Number of Measures Dropped	Number of Measures Remaining
Original Count	-	268

[17] The analysis began with 1,611 installed measures plus 240 recycled refrigerators and 77 recycled freezers among non-participants, for a total of 1,928 measures.

Adjustment 1. Removed Measure Types	78	190
Adjustment 2. Review of ‘Other” Responses	27	163
Adjustment 3. Questionable Measure Counts	11	152
Adjustment 4. Contractor Review	27	125
Adjustment 5. Kit Measure Adjustments	22	103
Final Count of NPSO-Eligible Measures	-	**103**

Adjustment 1. Removed Measure Types. We made several adjustments to the measure types that could qualify for NPSO, after considering the potential for self-report bias and the measures' impacts on the NPSO estimate when extrapolating to the population of Ameren Missouri non-participants.

- **Advanced power strips.** We removed 71 advanced power strips from consideration for NPSO savings due to likely survey measurement error on this measure. The program-discounted "like" measure is a Tier 2 power strip that has an $80 retail price before program discounts. The Energy Efficient Products program only sold 60 Tier 2 power strips. We did not think it was likely that our survey non-participants purchased an even greater number without a discount. It is possible that they purchased less expensive Tier 1 strips, but we also know that many respondents confuse a regular multi-outlet power strip with advanced power strips, despite providing descriptions in the survey question. We had several respondents who said they had purchased 5 or more advanced power strips, suggesting confusion. Moreover, in the 2019 Ameren Missouri baseline study, 29% of respondents reported having an advanced power strip in the baseline survey. We were unable to verify any of the self-reported advanced power strips during the in-home audits. For these reasons, we felt it was best to remove advanced power strips as an NPSO qualifying measures.
- **GSHPs.** We removed the seven GSHPs that two respondents reported installing (one respondent reported installing 6 GSHPs). GSHPs have low market share and significant up-front installation costs. We attempted to contact both respondents by phone numerous times to verify the type and quantity of equipment installed as well as the influence of Ameren Missouri but were unsuccessful. Given the substantial savings per unit (11.7 MWh) and the impact these two respondents could have on total NPSO savings, we did not feel comfortable including them without verification and dropped them from the analysis.

Adjustment 2. Review of "Other" Responses: Several of the survey questions that informed Criteria C – F contained "other" options where the respondent could input an open-ended answer. These responses required review for whether they were an NPSO qualified response. The questions that allowed an "other" response covered the following topics: reasons why respondents thought the measure was energy efficient (Criterion C); reasons respondents did not apply for rebates even though they were aware of them (Criterion D); whether the respondents installed the measures to save energy or money (Criterion E); and whether the measure saved electricity based on heating and cooling or water heating fuel type (Criterion F). We removed a total a 27 measures based on this review, as shown in Table 89.

Table 89. Adjustments of "Other" Survey Responses

Reason/Measure	Number of Measures Removed
Did Not Pass Criterion D	
Bathroom faucet aerator	3
CAC	3

Reason/Measure	Number of Measures Removed
DMSHP	2
Kitchen faucet aerator	2
Low-flow showerhead	1
Pool pumps	1
Subtotal	*12*
Did Not Pass Criterion E	
Bathroom faucet aerator	4
CAC	1
Kitchen faucet aerator	1
Pool pumps	1
Subtotal	*7*
Did Not Pass Criterion F	
Bathroom faucet aerator	3
Kitchen faucet aerator	2
Low-flow showerhead	1
Hot water pipe insulation	2
Subtotal	*8*
Grand Total	**27**

Note: We reviewed responses for Criterion C but did not remove any measures in those cases.

Adjustment 2. Questionable Measure Counts: Three respondents reported that they installed a quantity of measures that seemed larger than typical. For instance, one respondent reported installing 10 bathroom faucet aerators. We attempted to contact these customers by phone and visually inspected photos of their properties available on Google Maps to ensure that the respondents' addresses were not a multifamily property or otherwise inordinately large. After a maximum of five attempts, we were only able to contact two respondents and both cases resulted in adjustments. For the remaining seven respondents, we adjusted their measure counts to reflect the average of the other respondents in the analysis. Table 90 summarizes the results of this analysis.

Table 90. Questionable Measure Count Adjustments

Case	Quantity Reported	Adjustment	Phone Verified?	Number of Measures Removed
1	10 bath aerators	Count as 2 aerators, which is the average among other respondents.	No	8
2	3 kitchen aerators	Count as 1 aerator, which is the average among other respondents.	No	2
3	2 HPWHs	Changed to 1. Respondent confirmed they installed 1.	Yes	1
Total Measures Removed				**11**

Adjustment 3. Contractor Review: For space conditioning and water heating equipment (i.e., CAC, ASHP, DMSHP, HPWH, and furnace fan with ECM), we asked respondents what contractor they used, if any. We removed any respondents who used a contractor on the Ameren Missouri participating contractor list to

avoid double counting savings from participating contractor NPSO we estimated through the HVAC program evaluation. We also removed any respondents who could not confirm the contractor they used to be conservative about the possibility that they used a participating contractor. As shown in Table 91, we removed 28 measures based on this review. Notably, these adjustments in combination with earlier adjustments eliminated all ASHPs and DMSHPs from consideration for NPSO savings.

Table 91. Contractor Review Adjustments

Reason/Measure	Number of Measures Removed
Used a Participating Contractor	
CAC	9
Furnace Fan with ECM	6
ASHP	2
Subtotal	*17*
Could Not Confirm Contractor Name	
CAC	5
HPWH	2
Furnace Fan with ECM	1
ASHP	1
DMSHP	1
Subtotal	*10*
Grand Total	**27**

Adjustment 5, Kit Measure Adjustments. Ameren Missouri distributed 21,519 energy efficiency kits through schools in PY2019. Undoubtedly, some of our survey respondents had children who brought a kit home, but we are unable to remove these households from our analysis because the program does not track the identities of kit recipients. Therefore, it is possible that some of the kit measures that survey respondents report installing came from the school kits. To ensure we are not double counting savings from the kit measures, we estimated an adjustment factor for each kit measure that takes into account the percentage of Ameren Missouri non-participating survey respondents that likely received a kit based on the total number distributed, the percentage of kit recipients that installed the measures based on our Efficient Kits Program evaluation, and finally, and the percentage of NPSO-eligible kit measure installations that passed the NPSO screening criteria. As a result of this adjustment, we removed 22 total measures, as shown in the table below.

Table 92. School Kits Adjustments

Kit Measure	Number of Measures Before Adjustment	Adjustment Factor Based on Market Study	Measures Removed	Adjusted Number Measures
Kitchen faucet aerator	12	17%	2	10
Bathroom faucet aerator	16	50%	8	8
Low-flow showerhead	22	27%	6	16
Hot water pipe insulation	12	50%	6	6
Total	**62**	N/A [a]	**22**	**40**

[a] We applied adjustments as the measure level.

Final NPSO Estimate

Table 93 and Table 95 below summarize our calculation of kWh electric and kW demand NPSO savings, respectively, among survey respondents. The first and second columns show the final list of NPSO measures and quantities. The third column shows the adjusted quantity after applying partial savings credit based on Criterion B (see Figure 19). We arrived at total NPSO savings among surveyed non-participants by applying the adjusted measure quantities to the average savings values for each measure (see Table 76 for the sources of these savings values). We estimated a total of 35.6 MWh in NPSO among surveyed respondents. Pool pumps were the largest contributor to MWh NPSO savings, due mostly to the large savings value per measure. Recycled refrigerators and freezers (31% together) and advanced thermostats were the next largest contributors, due mostly to the quantities of these measures. These four measures together represent 81% of MWh NPSO savings.

Table 93. NPSO Among Survey Respondents (kWh)

Measure	Quantity	Adjusted Quantity (Applied 0.25 for Partial Credit) (A)	kWh Savings per Measure (B)	Total NPSO Among Survey Respondents (A * B)	% of NPSO
Pool pump	6	6.0	2,050	12,300	35%
Recycled refrigerator	13	8.5	858	7,293	20%
Advanced thermostat	20	11.8	450	5,288	15%
Recycled freezer	9	5.3	776	4,074	11%
CAC	8	5.8	493	2,835	8%
Furnace Fan with ECM	5	2.8	585	1,609	5%
Heat pump water heater	2	0.5	2,507	1,254	4%
Low-flow showerhead	16	9.5	71.66	678	2%
Kitchen faucet aerator	10	5.6	29.75	167	<1%
Hot water pipe insulation	6	3.4	37	125	<1%
Bathroom faucet aerator	8	2.8	6.17	17	<1%
Total	**103**	**61.7**	**N/A**	**35,639**	**100%**
Average Savings Per Measure	**35,639 ÷ 103 = 346 kWh**				

Note: For like measures that Ameren Missouri distributed in kits, we applied an adjustment factor to account for measures distributed through school kits. As a result, some of adjusted quantities for these measures are not in increments of 0.25.

We estimated a total of 10.05 kW in demand NPSO among surveyed respondents. Pool pumps, CACs, and advanced thermostats represented over three-quarters (77%) of demand NPSO.

Table 94. NPSO Among Survey Respondents (kW)

Measure	Quantity	Adjusted Quantity (Applied 0.25 for Partial Credit) (A)	kW Savings per Measure (B)	Total NPSO Among Survey Respondents (A * B)	% of NPSO
Pool pump	6	6.0	0.48291	2.897	29%
CAC	8	5.8	0.46673	2.684	27%
Advanced thermostat	20	11.8	0.17646	2.073	21%
Recycled refrigerator	13	8.5	0.11093	0.943	9%
Furnace fan with ECM	5	2.8	0.27266	0.750	7%
Recycled freezer	9	5.3	0.09717	0.510	5%
Heat pump water heater	2	0.5	0.20376	0.102	1%
Low-flow showerhead	16	9.5	0.00636	0.060	1%
Kitchen faucet aerator	10	5.6	0.00264	0.015	<1%
Hot water pipe insulation	6	3.4	0.00330	0.011	<1%
Bathroom faucet aerator	8	2.8	0.00055	0.002	<1%
Total	**103**	**61.7**	N/A	**10.047**	**100%**
Average Savings Per Measure	**10.047 ÷ 103 = 0.098 kW**				

Note: For like measures that Ameren Missouri distributed in kits, we applied an adjustment factor to account for measures distributed through school kits. As a result, some of adjusted quantities for these measures are not in increments of 0.25.

Next, we determined that the total non-participant population in Ameren Missouri's territory was 637,968 customers by comparing the Ameren Missouri customer database to the program tracking data. Table 95 below shows our calculation steps.

Table 95. Ameren Missouri Non-Participant Population

Step	Description	Number of Customers	Source
A	Total Ameren MO Customers	935,186	Customer database
B	Total 2019 Program Participants	297,218	Program tracking data
C	Total Non-Participants in Ameren Missouri Territory	637,968	A – B
D	Total Non-Participant Respondents	3,450	Survey data cross-referenced with participant lists

Note: The program participant count excludes upstream Residential Lighting, Peak Time Savings, and Multifamily programs.

We determined the total NPSO among Ameren Missouri customers by extrapolating the average savings among surveyed non-participants (n=3,450) to the population of Ameren Missouri customers who are non-participants (N=637,968). The total NPSO among Ameren Missouri non-participants was 6,590 MWhs and 1.86 MWs. Table 96 below shows our calculation steps.

Table 96. Total NPSO Among Ameren Missouri Customers

Step	Description	MWh Result	MW Result	Source:
A	Average kWh Savings per Measure	346	0.098	Survey data; PY19 impact evaluation
B	Number of Measures	103	103	Survey data
C	Number of Nonparticipant Respondents	3,450	3,450	Survey data cross-referenced with participant lists
D	Total Residential Population Minus PY18 Participants	637,968	637,968	Customer database
E	**Total NPSO MWh**	**6,590**	**1.86**	**(((B ÷ C) × A) × D)/1000**

Program Allocation

The last step was to allocate NPSO to each program based on the relative size of its ex-post gross savings. The specific allocations per program are in Table 97 and Table 98 below. NPSO represented 13.7% of the ex-post gross MWh savings and 7.7% of the ex-post gross MW savings among these programs.

Table 97. NPSO Allocation by Program (MWh)

Program	Ex-Post Gross Savings (MWh)	% Share	NPSO Allocation (MWh)	NPSO as % of Gross Savings
HVAC	35,796	75%	4,924	13.7%
Energy Efficient Products	4,922	10%	675	
Appliance Recycling	2,019	4%	277	
Energy Efficient Kits	5,205	11%	714	
Total	**48,027**	**100%**	**6,590**	

Table 98. NPSO Allocation by Program (MW)

Program	Ex-Post Gross Savings (MW)	% Share	NPSO Allocation (MW)	NPSO as % of Gross Savings
HVAC	21.27	88%	1.64	7.7%
Energy Efficient Products	1.57	7%	0.12	
Energy Efficient Kits	0.98	4%	0.08	

Program	Ex-Post Gross Savings (MW)	% Share	NPSO Allocation (MW)	NPSO as % of Gross Savings
Appliance Recycling	0.28	1%	0.02	
Total	**24.10**	**100%**	**1.86**	

Appendix B. HER Behavioral Persistence Estimation Literature Review

Introduction

HER programs are designed to promote changes in energy consumption behaviors that will result in reduced electricity or gas usage. Commonly, a residential customer will receive emailed and/or paper reports that include 1) a comparison of their energy usage to similar households in the same service territory, 2) an analysis of their past energy usage, and 3) suggestions for behavior changes and/or discounts on equipment to install to reduce energy usage.

Recent literature on HER programs defines energy savings resulting from a year's delivery of reports as follows:

- Energy savings for new program participants is a reduction in use compared to pre-program participation energy usage.
- Energy savings for continuing participants is any reduction in use relative to the prior year, as well as any avoided savings decay that would have taken place if delivery of reports stopped.

This definition of HER program energy savings is commonly called **annual incremental savings**.

There are also **persisting savings**, which are the annual savings attributable to HERs sent in prior years. If HER delivery stops, some customers sustain energy saving behaviors because of the effect of receiving reports in prior years. These persisting or carryover savings from prior program years are part of the lifetime savings attributable to reports sent in prior years, rather than the annual incremental savings due to reports sent in the current year. Although energy savings for continuing participants are included in the incremental savings definition, these savings differ from persisting savings because they are additional usage savings relative to their prior year's energy usage, not continued savings due to prior HERs. Persisting savings decline once a customer stops receiving reports.

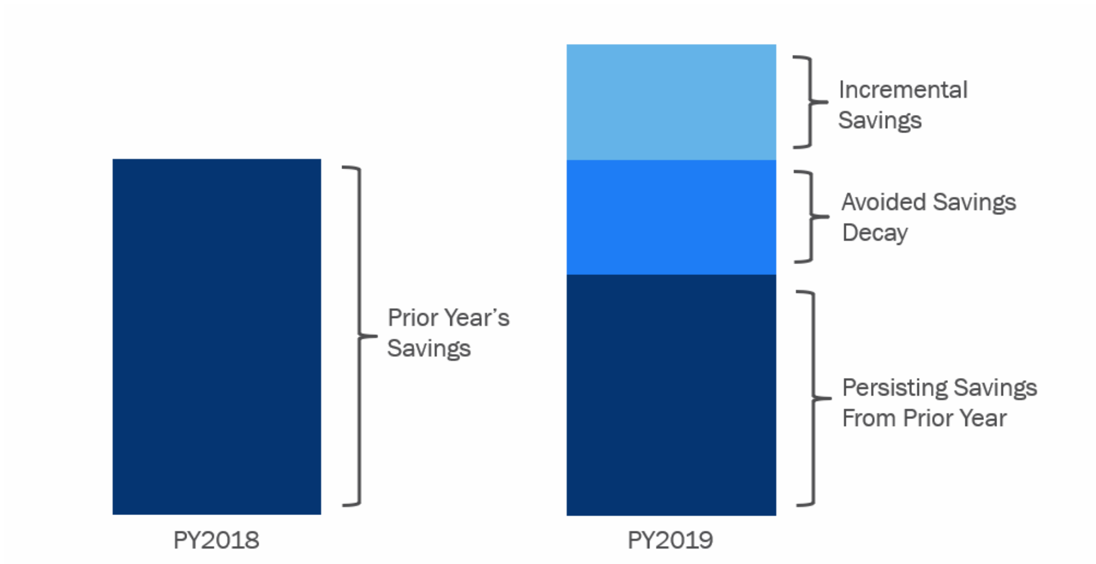
Total annual savings include incremental savings from the current year's reports as well as persisting savings from prior years' reports. HER programs yield the most savings in the first or second year and eventually decline and plateau in successive years -- even if the customer continues to participate and receives additional HERs during successive years. This is called **savings decay**. It is important to credit the continued HER program with avoiding savings decay that would otherwise have taken place. This is done by measuring the rate at which savings decline after report delivery has stopped (potentially over a period of years).

Ameren Missouri's program, which has two smaller legacy waves and one large new wave, has both annual incremental savings for new participants and persisting savings from customers that have already been treated in prior years, as well as avoided savings decay due to continued delivery of reports to legacy customers. Figure 24 below shows how overall savings in PY2019 can be regarded:

- incremental savings, due to additional savings for continuing participants relative to PY2018 and all savings for any new program entrants in PY2019;

- avoided savings decay in PY2019 due to continuing delivery of HERs to previously treated customers; and
- persisting savings from prior program years' treatment, which represents savings that would continue to accrue due to ongoing efficient behaviors by customers even if delivery of HERs was stopped in PY2018.

Figure 24. Illustration of Incremental, Persisting, and Avoided Decay Energy Savings



This focus on incremental savings, including avoided savings decay, represents an important shift in emphasis relative to a one year estimated life, which does not distinguish savings due to reports delivered in prior years. In the case of the Ameren Missouri HER Program, the Missouri TRM dictates a one-year EUL. Incremental savings more accurately account for the interventions that delivered energy savings over time. Expanding to a multi-year EUL will mean that annual savings credited to a given year's program activity are characterized by the upper two components of PY2019 in Figure 24 above. The lifetime savings from that year's program activity is then calculated as a function of the savings decay rate over time. Note that the savings decay rate estimated for a program provides an indication as to what the EUL should equal. For example, if the decay rate is 20% per year, then by year 5 there would be no incremental savings left and the EUL of five years would be considered appropriate.

Research Objectives

This evaluation includes a literature review of current methods and findings across the United States with respect to incremental annual savings from HER programs. The evaluation team provides estimates of decay, persistence and annual incremental savings from stoppage of treatment studies on HER programs operated around the United States. We provide a characterization of evaluation best practices and summarize findings across the studies conducted to date on rates of savings decay.

This review addresses the following questions:

- What methods have been used to estimate incremental annual savings, including savings persistence, for HER programs in the United States?

- What annual savings decay rates have been observed?

Studies Reviewed

Table 99 presents the six studies included in this literature review and a short description of the approaches used to estimate savings decay.

Table 99. Studies Reviewed and Methods Used to Estimate Savings Decay

Studies	Approach
Navigant (2019)	Billing Analysis + Annual Decay Rate Equation
Allcott and Rogers (2014)	Formal Long-Run Regression Model
Thomas, Huber and Smith (2016) Integral Analytics (2012) DNV-KEMA (2012) DNV-GL (2014)	Consumption Analysis

Navigant (2019)

Overview

Commonwealth Edison (ComEd), in tandem with Opower, began its HER program in July 2009, initially targeting 50,000 residential customers in a first wave. In 2019, there were three waves receiving treatment, which totaled 265,078 treatment customers and 105,678 control. Guidehouse, previously Navigant when this study was completed, conducted regular evaluations of ComEd's HER program, as well as savings persistence studies. The most recent study was completed in 2019.18

In this study, three subsets of participants were randomly selected to stop receiving reports in October 2013. The study uses the differences in energy consumption between the three sub-groups and those who continued receiving reports to form estimates of the decay rates, persistence rates, and estimated measure life for each group. More specifically, the study yields decay and persistence rates for the three years following the stoppage of treatment, from November 2013 through October 2016. In this study, the subset of participants that stopped receiving reports are referred to as the terminated report (TR) group, and the rest of the participants that continued to receive reports are referred to as the continued report (CR) group.

Of the reports covered in this literature review, this is the only one that estimated year-to-year decay rates rather than estimating an average decay rate for a certain period. In addition, the study included three subsets of suspended treatment customers. Although there were other studies where savings decay rates were estimated for more than one subset of treatment customers, the combination of estimating yearly decay rates along with multiple stoppage of treatment groups gives greater insight to which factors affect the average annual savings decay and adds more power to the analysis.

Methods

[18] Navigant (2019). "ComEd Home Energy Report Program Decay Rate and Persistence Study – Year Five Research Report." Chicago, Illinois: Navigant Consulting, Inc.

In this study, the decay rates for each sub-group of participants are calculated by comparing the subset of participants that stopped receiving reports from each wave to the participants that continued receiving reports. The study authors used a lagged dependent variable (LDV) regression model, as shown in Equation 69. Navigant also developed a linear fixed-effects regression (LFER) model as a form of triangulation and robustness check on the lagged dependent variable regression model. Across the two models, the coefficients for the program influence on savings were not statistically different at the 90% confidence level.

Navigant used a lagged dependent variable model and a linear fixed-effects regression model to examine persistence savings, savings decay and measure life for the ComEd HER program.

Equation 69. Navigant (2019) Lagged Dependent Variable Regression Model

$$ADU_{kt} = \beta_1 Treatment_k \cdot TR_k + \beta_2 Treatment_k \cdot CR_k + \sum_J \beta_{3j} Month_{jt} + \sum_J \beta_{4j} Month_{jt} \cdot ADUlag_{kt} + \varepsilon_{kt}$$

Where:

ADU_{kt} = is average daily usage of kWh by household *k* in bill period *t*

$Treatment_k$ = is a binary variable taking a value of 0 if household *k* is assigned to the control group, and 1
if assigned to the treatment group

TR_k = is a binary variable taking a value of 1 if household *k* is assigned to the terminated report group

CR_k = is a binary variable taking a value of 1 if household *k* is assigned to the continued report group

$ADUlag_{kt}$ = is household k's energy use in the same calendar month of the pre-program year as the calendar month of month t

$Month_{jt}$ = is a binary variable taking a value of 1 when *j* = *t* and 0 otherwise

The Navigant team also used a LFER to estimate program impacts alongside the LDV. The LFER is provided below in Equation 70.

Equation 70. Navigant (2019) Linear Fixed Effects Regression Model

$$ADU_{kt} = \alpha_{0k} + \alpha_1 Post_t + \alpha_2 Treatment_k \cdot TR_k \cdot Post_t + \alpha_3 Treatment_k \cdot CR_k \cdot Post_t + \varepsilon_{kt}$$

ADU_{kt} = is average daily usage of kWh by household *k* in bill period *t*

α_{0k} = captures household-specific effects on energy usage that do not change over time

α_1 = average effect across all households in the post-period

α_2 = effect of being in treatment group in post-period for terminated report group

α_3 = effect of being in treatment group in post period for continued report group

$Treatment_k$ = is a binary variable taking a value of 0 if household *k* is assigned to the control group, and 1 if assigned to the treatment group

TR_k = is a binary variable taking a value of 1 if household k is assigned to the terminated report group

CR_k = is a binary variable taking a value of 1 if household k is assigned to the continued report group

After running the LDV and LFER models, Navigant used the estimates to calculate the decay rate. They calculated the annual decay rate δ_t as "one minus the ratio of the percentage savings for the TR [terminated report] group in the t^{th} year after the reports were discontinued to percentage savings for the CR [continued report] group in that same year."[19] Equation 71 provides the annual savings decay rate calculation. The study calculated decay rates for each of the years following the stoppage of treatment for the TR group.

Equation 71. Year t Decay Rate

$$\delta_t = 1 - \frac{\%\ Savings\ for\ TR\ group\ in\ t^{th}\ year\ after\ reports\ stop}{\%\ Savings\ for\ CR\ group\ in\ t^{th}\ year\ after\ reports\ stop\ for\ TR\ group}$$

Navigant then uses δ_t, the annual decay rate for each year, to find the average annual decay rate. Equation 72 shows the calculation for the average annual decay rate. Average annual decay rate is then used to estimate lifetime persistence savings and measure life.

Equation 72. Average Annual Decay Rate

$$\Delta = -\frac{ln\,(1 - \delta_t)}{t}$$

Alcott and Rogers (2014)

Overview

This study examines the three oldest Opower HER programs in the country, which began in 2008 or 2009 and are in the Upper Midwest, the Northwest, and the Southwest United States. Hunter and Alcott were asked not to identify the utilities in their study, so they are referred to by geographic region. A total of 234,000 residential customers were initially signed up to participate in these three HER programs. Households were randomly assigned to either stop treatment after two years or continue indefinitely. The study authors used regression modeling to estimate the average annual persistence rate of savings across the three programs for customers whose treatment was halted. The annual average decay rates were estimated after a little over two years after stoppage of treatment.[20]

The three programs vary in several ways, including the climate in which they operate, the number of customers that stopped receiving reports, the number of months participants were in the program before they were dropped, and the number of months participants stopped receiving reports. Using the same regression model to estimate savings decay for the three subgroups that stopped receiving HERs controls for many of these differences. This provides greater opportunity to compare decay rates across groups. Like the Navigant (2019) study, this study offers insight into the varying factors that can affect decay rates.

[19] Ibid.

[20] Hunt Allcott, Todd Rogers (2014). The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003-3037. doi: 10.1257/aer.104.10.3003.

Methods

These models compare energy consumption for participants that stopped receiving reports to the consumption of participants that continued receiving reports, to estimate the average annual persistence rate for each utility. Analysts ran a formal long-run regression model by creating four periods. Period 0 is the pre-treatment period, 1 is the first year of treatment, 2 is the second year, and 3 is the post-treatment period. The primary equation for estimating persistence for each utility is Equation 73 below.

Equation 73. Average Annual Persistence Savings

$$
\begin{aligned}
Y_{itm} = {} & (\tau^0 P_m^0 + \tau^1 P_m^1 + \tau^2 P_m^2) \cdot T_i \\
& + (\alpha^0 P_m^0 + \alpha^1 P_m^1 + \alpha^2 P_m^2) \cdot E_i \\
& + (\tau^3 T_i + \alpha^3 E_i) \cdot P_m^3 \\
& + (\delta^{LR} r_t D_i + \rho r_t E_i + \omega r_t) \cdot P_m^3 \\
& + \mathbf{M}_{im}(P_m^2 + P_m^3) \cdot (T_i \psi_1 + \psi_2) \\
& + \boldsymbol{\theta}_m \mathbf{Y}_{im}^b + \boldsymbol{\pi}_m + \varepsilon_{itm}.
\end{aligned}
$$

Where:

Y_{itm}	=	Household *i*'s average daily electricity usage for the bill period ending on date *t* in the month of sample *m*
τ^p	=	dropped group treatment effects
α^p	=	difference between continued and dropped group effects
P_m^p	=	indicator variables for whether month *m* is in period *p*
δ^{LR}	=	treatment effect decay rate for the dropped group (kWh/day/year)
ρ	=	trend in the continued group treatment effect (kWh/day/year)
r_t	=	time (in years) since the beginning of period 3
M_{im}	=	average heating degrees and average cooling degrees for household *i* in month
D_i	=	indicator variable for whether household *i* stopped received treatment (was dropped)
E_i	=	indicator variable for whether household *i* continued treatment
T_i	=	indicator variable for combined households *i* with both those who dropped and continued treatment ($D_i + E_i = T_i$)
Y_{im}^b	=	Household *i*'s average electricity usage in baseline period *b* for month *m*
$\theta_m Y_{im}^b$	=	month by year controls for baseline usage
π_m	=	month by year intercepts

ε_{itm} = error term for household *i* at time *t* (in years) and month *m*

To estimate persistence, the study compared the results of the continued treatment group to the discontinued group in the post-drop period. The α^3 and τ^3 point estimates suggest the difference in savings of the dropped participant group compared to the continued group in the post-drop period.

Thomas, Huber and Smith (2016)

Overview

There are very few instances where a program is discontinued, and then renewed some time afterwards. This happened for two electric distribution companies in Pennsylvania. PPL Electric Utilities Company (PPL) and Duquesne Light Company discontinued its HER programs in 2013, but then restarted the programs in 2015.[21]

Following the renewal of these programs, the Pennsylvania Public Utility Commission had the Statewide Evaluation Team conduct a billing analysis to see whether the stoppage of treatment for all participants in 2013 created decay rates within these programs. These utilities cover different territories, and varying groups of participants, in Pennsylvania. PPL covers the eastern portion of the state, including smaller cities such as Williamsport, Scranton, and Harrisburg, while Duquesne sprawls out through Pittsburgh and its surrounding areas.

Methods

The study authors analyze decay rates by comparing the average annual savings of the treatment group during the suspended period to the average annual savings before the suspension of reports. They estimated the energy savings impacts before and after suspension of reports by using a linear fixed-effects regression (LFER) model. The regression model is provided in Equation 74.

Equation 74. Thomas, Huber and Smith (2016) Regression Model

$$DailyUse_{i,m} = \beta_0 + \beta_1 Post_m + \sum_i \gamma_i Acct_i + \sum_m \alpha_m D_m + \sum_m \theta_m Treatment_i Post_m$$

Where

$DailyUse_{i,m}$ = average daily usage in month *m* for customer *i*

i = index to represent each residential account

m = index to represent each month of each year of the analysis period

$Post$ = indicator variable to represent months after the start of the program

β_0, β_1 = model coefficients

$Acct_i$ = indicator variable for each account in the database

[21] Thomas, J., Huber, J., and Smith, J. “Residential Behavioral Program Persistence Effects in Pennsylvania.” ACEEE Summer Study on Energy Efficiency in Buildings, August 2016.

γ_I = fixed effects coefficient for account *i*

D_m = indicator variable for each month/year of the analysis period

α_m = coefficients for each month

$Treatment_i$ = indicator representing a customer in a treatment group

θ_m = coefficient representing average daily energy savings in month *m*

DNV-KEMA (2012)

Overview

Puget Sound Energy (PSE) has one of the longest active HER programs in the United States, going back to 2008. As of 2018, PSE had 96,000 participants and 51,000 control customers.[22] In the second year of the program, around 10,000 participants of the first wave were randomly selected to stop receiving reports. This study of savings decay rate was undertaken to make more informed program design decisions.[23]

Methods

A billing analysis was conducted by DNV-KEMA for the 10,000 suspended treatment customers relative to the continued treatment group. The model included three years of program data, with two years of both the continued and suspended treatment groups receiving reports, and then terminating the reports for the suspended group in the third year of the program. A heating and cooling model similar to the PRISM model was used to estimate energy usage for an average weather year. The resulting weather-normalized model of savings decay is shown in Equation 75.[24]

Equation 75. DNV-KEMA (2012) Regression Model

$$E_{im} = \mu_{im} + \beta_H H_{im}(\tau_H) + \beta_c C_{im}(\tau_c) + \varepsilon_{im}$$

Where

E_{im} = energy consumption during day *m* for customer *i*

$H_{im}(\tau_c)$ = normal heating degree-days calculated at the optimal heating base temperature τ_c of customer i

$C_{im}(\tau_c)$ = normal cooling degree-days calculated at the optimal cooling base temperature τ_c of customer i

$\mu_{im}, \beta_H, \beta_c$ = baseload, heating and cooling parameter estimates from the site-level models

ε_{im} = regression residual

[22] DNV-GL (2019). "PSE Home Energy Reports Program: 2018 Impact Evaluation – Updated Report."

[23] DNV-KEMA (2012). "Puget Sound Energy's Home Energy Reports Program: Three Year Impact, Behavioral and Process Evaluation." Madison, Wisconsin: DNV KEMA Energy & Sustainability.

[24] The PRISM (PRinceton Scorekeeping Method) is one of the first used regression models to study commercial building energy savings, initially published in 1986. Source: Institute for Building Efficiency (2013). "LEAN Energy Analysis: Using Regression Analysis to Assess Building Energy Performance." Accessed on December 3, 2019.

DNV-GL (2014)

Overview

This study by DNV-GL provides analysis of the same program as the 2012 report from DNV-KEMA. The main differences between the reports are the methods for estimating decay, the time over which the suspended treatment group stopped receiving reports, and the estimation method for average annual savings decay. These two studies do not estimate decay rates in each successive year following stoppage of treatment, but by comparing the results across studies, one can observe the different savings decay rates calculated based on different lengths of time following stoppage of treatment.[25]

Methods

The main difference between this and the 2012 report is the number of months the suspended treatment customers stopped receiving reports. The 2012 report included calculation of the decay rate as of one year following discontinuation of report delivery, while the 2014 study included an average annual decay rate estimate three years after stoppage of treatment. The other difference is that this report used a difference-in-difference modeling approach to estimate the decay rates. Creating a program as a randomized control trial allows the use of this model as the most direct and simplified approach for calculating the decay rates. Equation 76 shows the model used for this report.

Equation 76. DNV-GL (2014) Regression Model

$$\Delta C_i = \alpha + \beta T_i + \varepsilon_i$$

Where:

ΔC_i	=	pre-post difference in annual consumption for household i
α	=	intercept
T	=	treatment indicator (value of 1 if treatment and 0 otherwise)
β	=	treatment effect or savings estimate
ε	=	error term

Integral Analytics (2012)

Overview

Sacramento Municipal Utility District (SMUD) began its HER program back in 2008 as well, as a one-year pilot. After seeing the pilot's success, SMUD decided to transform it into a program, and added a second wave of participants in 2010. In 2012, there were approximately 80,000 participants in the program. In this study, the authors calculated decay by comparing the savings of the subset of suspended participants for

[25] DNV-GL (2014). "Residential Energy Efficiency Special Projects: 2014 Impact Evaluation of Home Energy Reports Program." Madison, Wisconsin: DNV-GL.

the first wave for the first two years they were in the program with the savings the year following the stoppage of treatment.[26]

Methods

Similar to the Thomas, Huber and Smith (2016) study, this analysis featured a linear fixed effects model to estimate energy savings impacts but used the general application of a fixed effects model rather than an LDV model. The regression model for this report is presented in Equation 77.

Equation 77. Integral Analytics (2012) Regression Model

$$y_{it} = \alpha_1 + \beta x_{it} + \varepsilon_{it}$$

Where:

y_{it} = energy consumption for home *i* during month *t*

α_i = constant term for site *i*

β = vector of coefficients

x_{it} = vector of variables that represent factors causing changes in energy consumption for home *i* during month *t* (i.e., weather and participation)

ε_{it} = error term for home *i* during month *t*

The study authors fit a 4th order polynomial trend line to the data to estimate the decay rate after the stoppage of treatment. The analysts used this trend line to approximate the decay rate two years after the suspension of treatment for the sub-group of participants in the program.

Key Findings

Our study review led to the following findings to the research questions we posed:

- What methods have been used to estimate incremental annual savings, including savings persistence, for HER programs in the United States?
  - The studies we reviewed were of HER programs designed as RCTs and relied on selective stoppage of treatment to estimate decay rates. This means that treatment of a subset of a cohort ceased, thereby allowing greater power to estimate savings decay rates since a portion of the same cohort continued to receive HERs. This method has a great deal of power to estimate savings persistence as selective stoppage of a subset of treatment customers provides ideal comparisons of customers who began treatment at the same time.
- What annual savings decay rates have been observed?
  - The studies estimated decay rates ranging from 1% to 60% of average annual savings decay suggesting that estimated decay rates are highly variable.

[26] Integral Analytics (2012). "Impact & Persistence Evaluation Report: Sacramento Municipal Utility District Home Energy Report Program." Cincinnati, Ohio: Integral Analytics, Inc.

Table 100 and Table 101 summarize the findings across studies by presenting a simplified comparison of their results.

Table 100 presents annual savings decay rates by year and the five-year average annual decay rate for three different waves that ceased receiving HERs in ComEd's program, based on findings from in Navigant's study (2019). The five-year average annual savings decay for Wave 1 customers, who received HERs for over 4 years before experience a stoppage in reports, is 20%. The rate falls to just over 18% for Wave 3 who participated in the HER program as treatment customers for 2.5 years before they stopped receiving reports. Wave 5 customers, who were treated for a little over a year before reports were discontinued, showed a much higher average annual decay rate of over 45%. Based on this study alone, one might conclude that length of treatment before reports are discontinued has a large impact on the savings decay rate. This finding is relevant to Ameren Missouri since it began its HER Program in 2016 and has launched additional waves through 2019, some of which have ceased receiving HERs.

Table 100. Navigant (2019) Decay Rates by Wave and Year

Study	Wave	# of Months in Program	Stoppage of Treatment Customers	Annual Savings Decay (Year 1)	Annual Savings Decay (Year 2)	Annual Savings Decay (Year 3)	Annual Savings Decay (Year 4)	Annual Savings Decay (Year 5)	Average Annual Savings Decay
Navigant (2019)	Wave 1	52	5,420	4%	15%	39%	28%	14%	20%
	Wave 3	30	6,583	2%	17%	18%	24%	31%	18.4%
	Wave 5	16	4,193	22%	60%	47%	38%	65%	46.4%

The key study characteristics and findings are shown in Table 101 for the other studies we reviewed. The studies in in this table did not report decay rates by year but rather reported average annual decay rates. Also, two of the studies below did not report incremental percent savings per customer, which are therefore indicated as NA. While all of the studies covered in this literature review are applicable to Ameren Missouri's HER program in terms of a similar core program design and general recommended evaluation approach, the study design employed by Navigant (2019) is considered the most applicable in terms of its approach to Ameren Missouri should its program staff decide to conduct its own study to determine savings persistence for its HER program. We recommend Navigant's approach applied to evaluate savings persistence of Ameren Missouri's HER Program since it is the only study to have calculated both individual annual savings decay rates and overall annual average decay rates over multiple years.

Table 101. Average Annual Decay Rates from Reviewed Persistence Studies

Study	Utility/Territory Covered	# of months between reports	# of Months in Program	# of Months of Treatment Stoppage	Stoppage of Treatment Customers	Incremental Savings (Per Customer)	Average Annual Savings Decay
Allcott and Rogers (2014)	Upper Midwest	60% monthly and 40% quarterly (randomly assigned)	24-25	26	12,368	NA	21%
	Northwest	72% monthly and 28% quarterly	24	29	11,543	NA	18%

Study	Utility/Territory Covered	# of months between reports	# of Months in Program	# of Months of Treatment Stoppage	Stoppage of Treatment Customers	Incremental Savings (Per Customer)	Average Annual Savings Decay
		(randomly assigned)					
	Southwest	71% monthly (heavier users) and 29% quarterly (light users)	25-28	34	12,117	NA	15%
Thomas, Huber and Smith (2016)	PPL	monthly	38	16	48,700	2.0%	30%
		monthly	24	16	52,900	1.7%	22%
	Duquesne Light Company	monthly	10	21	52,200	1.0%	1%
Integral Analytics (2012)	SMUD	71% monthly and 29% quarterly (randomly assigned)	27	12	9,965	1.6%	32%
DNV-KEMA (2012)	Puget Sound Energy	75% monthly and 25% quarterly (randomly assigned)	24	12	9,674	NA	21%
DNV-GL (2014)	Puget Sound Energy	75% monthly and 25% quarterly (randomly assigned)	24	36	7,796	1.1%	11%

Looking at the findings across studies, there is no clear pattern in terms of first year decay rate as a function of how long customers participated in the HER program prior to stoppage of treatment. In Table 100 for example, a comparison of the annual decay rates for the first two years suggests that a longer period receiving reports before stoppage is correlated with a lower decay rate of savings; Wave 1 was in the treatment period before termination for the longest period and had the smallest change in decay rates between the first two years, while Wave 5 was in the treatment period for the shortest time and has the largest change in yearly decay rates. This would make intuitive sense, since as a participant receives more reports, it could provide more opportunity to adopt energy efficient habits that could then take longer to "wear off" than for participants who stopped receiving reports after a shorter participation period. However, the Thomas, Huber and Smith (2016) study in Table 101 shows the opposite pattern. In that study, participants who were in the program for a longer period of time have higher average annual decay rates once they experienced a stoppage in reports. Thomas, Huber and Smith (2016) estimated decay for two waves within the PPL territory and found that the decay rate for the wave that had participants in the program for 36 months was higher than that for the wave that was in the program for 24 months. This is the opposite of what Navigant (2019) found. At this point, until there is further research, it is unclear if there is a general trend for how the average annual decay rate changes based on the amount of time a participant is in a HER program.

Results are also mixed as to whether decay rate over a period of years after stoppage of treatment is linear or curved. The study that has addressed this question most directly to date is the Navigant (2019) study highlighted in Table 100. Results from this study suggest that the decay rate increases greatly for each wave in the second year following the suspension of reports. The decay rate also increases from the second to the third year for Wave 1 and Wave 5, although it decreases for Wave 3. This pattern would suggest that energy saving behaviors tend to fall off slowly at first following stoppage of treatment, and that this rate of falling off accelerates over time. However, the Allcott and Rogers (2014) study highlighted in Table 101 shows a different pattern and suggests that as the number of months increases, the average annual decay rate decreases. This trend is also apparent when comparing the DNV-KEMA (2012) and DNV-GL (2014) studies in Table 101. This latter pattern would suggest that decay rates are higher during the months immediately following the suspension of reports, and then gradually decrease as the months continue. A possible explanation for this latter pattern is once customers stop receiving reports, they quickly lose the energy saving methods that were not incorporated into their daily routines; what remains is the behaviors they either had before they enrolled in the program and/or ones they engrained into their lifestyle through the program. The same as with the observations of first year decay rate as a function of length of time in the program, decay rates as a function of time elapsed since stoppage of treatment do not show a clear trend line across studies.

Recommendations

All the studies in this literature review emphasize the selective stoppage of treatment as the established and standard method for measuring avoided decay. **We therefore recommend Ameren Missouri conduct a persistence study to better understand how savings from its HER Program decay over time and to inform future decisions about the appropriate EUL for HERs**. The evaluation team recommends the same study design where subsets of existing cohorts stop receiving HERs so that the change in savings between customers who continue to receive treatment can be compared to those who stopped receiving treatment.

While it is important to acknowledge that the different studies had different sample sizes, different study lengths, and some differences in modeling approach, it is worth observing that the unweighted average annual decay rate across studies was 20% and that nine of the twelve studies reviewed yielded an average annual decay rate between 10%-30%. A recently completed literature review of HER persistence studies by Guidehouse (formerly Navigant) found an average annual decay rate of 21%. **In the short term, we recommend Ameren Missouri maintain its EUL of one year but use results of its own persistence study to determine a more appropriate value for its program.** Findings from other studies suggest an assumption of an EUL greater than 1, however changing the EUL assumption has implications, particularly on program design. Persistence and decay rate studies are critical to understanding whether and how savings degrade in the absence of a program intervention, as well as providing more accurate lifetime savings results.

Appendix C. Low-Income Pre-Period Consumption Data Analysis

Ameren Missouri and its low-income program implementers have two unique program performance metrics that are designed to incentivize the pursuit of deeper savings per property and provide a holistic assessment of the program's impact. Specifically, these metrics track the program's impact in terms of (a) a threshold criterion to spend at least 85% of the Commission-approved annual budget for administration and incentives each program year and (b) the average percent energy savings per property. While inputs for the first metric come directly from Ameren Missouri's accounting system, evaluators provide the inputs to calculate the average percent of site savings metric. This appendix details the evaluation team's methodology and results.

Following 2019-21 MEEIA Energy Efficiency Plan guidance, the evaluation team is providing the two key inputs to calculating average percent site savings, including the Single-Family Low Income program's evaluated energy savings and the total billed energy consumption in the 12 months pre-participation (pre-period consumption). These items serve as inputs into the Earnings Opportunity Calculator and enable calculation of the percent energy savings per property as the program's total evaluated energy savings divided by the total billed energy consumption for all the properties served during the program year.

Analytic Method

To calculate pre-period consumption, we used information collected from Ameren Missouri's customer billing data and from PY2019 program tracking data. Opinion Dynamics reviewed all datasets for accuracy and completeness. The description of each data source is below.

- **Program Tracking Data:** Franklin Energy provided Opinion Dynamics with a participant tracking file that included all PY2019 program participants, representing participation through December 2019. This file contained descriptive information for each participant, including unique customer identifiers, contact information, participation date, measures installed, and ex ante savings.
- **Customer Billing Data:** Ameren Missouri provided historic monthly electric billing data for all customers through November 2019. The billing data included the account number, premise number, meter number, billing dates, and usage values.[27]

As the first analysis step, we extracted customer billing data for program participants in the tracking data. The evaluation team also examined the structure of the customer billing data.[28] Numerous premises had multiple accounts during the pre-period such as could be due to tenant turnover, bill non-payment resulting in account conversion to a landlord, or other reasons. This was particularly true for Multi Family premises (61%) and to a lesser extent Single Family premises (26%). We included all bills available during the pre-period for each premise, including all accounts associated with the premise. We treated gaps in service (such as between one account's last bill period and another account's first bill period) as 0 usage. We retained bill periods recorded in the billing data as 0 kWh usage, preserved both low (<2 kWh average daily consumption) bill periods and high (>300 kWh average daily consumption) bill periods as-is, and used any estimated meter reads not replaced by an actual reading.

[27] Billing data are provided to use on a weekly cadence and due to the timing of the data cleaning and prep, we leveraged the data provided by Ameren Missouri through November.

[28] For each participating premise, we extracted history of billing records across all accounts associated with that premise.

We also assessed pre-period consumption data coverage across all electric accounts associated with a single premise. Eleven premises across the two programs (less than 1% of participants) had no or fewer than 12 months of consumption data. Table 102 summarizes these cases. Following Ameren Missouri's 2019-2021 MEEIA Energy Efficiency Plan, we did not drop or annualize usage for the accounts with fewer than 12 months of pre-period consumption data.

Table 102. Participant Pre-Period Consumption Data Availability

Drop Reason	Single Family Low-Income		Multi Family Low-Income	
	N	% Remaining	N	% Remaining
Total Customers	491	100%	824	100%
Not in raw billing data	-1	99%	-5	99%
Less than 6 months of data	0	99%	-3	99%
More than 6 but fewer than 12 months of data	-2	99%	0	99%
Usage data equaling zero for entire pre-period	0	99%	0	99%
Customers will 12 months of data	489	99%	816	99%

Given the small number of PY2019 projects with less than 12 months of pre-period usage data, the evaluation team feels that the planned approach of retaining all consumption data as recorded in the Ameren Missouri billing database adequately represents the total annual electricity usage across all program participants. The results in Table 103 can be input to the Earnings Opportunity Calculator as a basis for understanding the ex post annual savings from our ex post impact evaluation.

Table 103. Participant Pre-Period Consumption

Usage	Single Family Low-Income			Multi Family Low-Income
	Single Family (n=389)	Mobile Home (n=97)	Total (n=486)[29]	Total (n=824)
Total Annual kWh	6,161,318	1,610,310	7,771,628	6,204,307

[29] Single Family Low-Income program tracking data changed after we conducted this analysis, and one new participant (premise) was added for which we do not have consumption data. Additionally, five Single Family participants (premises) had neither ex ante nor ex post kWh savings. Our final pre-period consumption totals for the Single Family Low-Income program exclude these six participants.

Appendix D. Data Collection Instruments

Data collection instruments are provided under separate cover.

For more information, please contact:

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