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Opinion Dynamics

RESIDENTIAL ENERGY ASSESSMENT PROGRAM EVALUATION REPORT

DUKE ENERGY CAROLINAS AND PROGRESS

FINAL

NOVEMBER 27, 2023

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I. EXECUTIVE SUMMARY

1.1 PROGRAM SUMMARY

The Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) Residential Energy Assessments (REA) Program is a home assessment program that provides customers with a customized energy report with low- and no-cost recommendations to help lower energy bills. Customers also receive an energy efficiency starter kit that contains two LED bulbs,[1] one low-flow showerhead, two faucet aerators (one kitchen and one bathroom), weatherstripping, six switch and outlet seals, and a Department of Energy (DOE) booklet of energy savings tips. Through the end of 2020, the program also offered up to six free standard LEDs. In 2021, the program began offering free additional bathroom faucet aerators and free pipe wrap, as well as discounted specialty LEDs (globe, candelabra, and recessed lighting LEDs), handheld showerheads, and smart thermostats in addition to the starter kit. The energy specialist (or auditor) who performs the assessment must install purchased discounted measures, and may install any kit measures that the customers allows. The program auditors also encourage behavioral changes related to energy use and recommend higher-cost energy-saving investments to customers, such as new energy-efficient appliances.

The REA Program targets owner-occupied, single-family residences. Homes must have an electric water heater, electric space heating, or central air conditioning to be eligible for participation. Our evaluation includes 10,171 households in the DEC jurisdiction and 5,996 households in the DEP jurisdiction that participated in the program between September 1, 2020, and August 31, 2021 ("the evaluation period").

1.2 EVALUATION OBJECTIVES

This evaluation included an analysis of gross and net impacts as well as an assessment of program processes.

1.2.1 IMPACT EVALUATION

The impact evaluation addressed the following key objectives:

- Estimate net energy savings at the household level, using consumption analysis;
- Review and update, as necessary, deemed savings values for program measures, through a review of measure assumptions and calculations;
- Develop measure-level in-service rates (ISRs);
- Estimate measure-level gross energy, and summer and winter peak savings, using engineering analysis;
- Apply kW to kWh summer and winter peak demand reduction ratios from the engineering analysis to the consumption analysis-based net energy savings to estimate program summer and winter peak demand savings;
- Assess the free-ridership (FR) associated with free and discounted program measures;
- Document spillover (SO) associated with program participation; and
- Develop DSMore inputs for the energy efficiency starter kit and the additional free and discounted program measures.

[1] The starter kit contained two standard LED bulbs until December 2020 but switched to two candelabra LED bulbs in January 2021.

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To achieve these research objectives, Opinion Dynamics completed several data collection and analytic activities, including an interview with the program manager, a participant survey, an analysis of program tracking data, a consumption analysis, a deemed savings review, and an engineering analysis. Based on responses to the participant survey, the evaluation team developed estimates of measure-level ISRs and net-to-gross ratios (NTGRs).

1.2.2 PROCESS EVALUATION

The process evaluation addressed the following research questions:

- What are the most successful components of the program? What improvements can be made to the program's design and implementation?
- What marketing channels are most effective in motivating customers to participate in the REA Program?
- What proportion of participants are choosing to install smart thermostats, specialty lighting, handheld low-flow showerheads, and/or opt for blower door tests for a discounted cost?
- Are customers satisfied with the participation process and program measures?
- What are the challenges associated with program participation?
- Do participants find the assessment recommendations useful and actionable?
- Does the REA Program inform eligible customers of other energy-saving opportunities, and are they channeled into other Duke Energy programs?
- What kind of behavioral changes do participants make following the assessment?

1.3 KEY FINDINGS

1.3.1 IMPACT FINDINGS

Table 1 presents the annual net savings results of our impact analysis for the DEC and DEP jurisdictions, on a per household basis as well as for the program overall. Results reflect savings from the starter kit, additional free and discounted measures, and savings from behavioral changes made based on the assessment recommendations and participant SO attributable to the program. Estimated per household savings of 559 kWh for DEC and 743 kWh for DEP are lower compared to the last evaluation.[2] Possible drivers of this decrease include the naturally increasing efficiency of lighting choices and low ISRs for free measures, and a smaller share of DEC participants with electric heat compared to DEP. In addition, the evaluation period reflects conditions in a post-COVID environment, which may impact the use of lighting and HVAC equipment, and thus affect savings, and may also have affected customers' willingness to let auditors install measures (potentially explaining the low ISRs for free measures).

[2] The last evaluation estimated annual per household savings of 693.5 kWh for DEC and 1,095 kWh for DEP.

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Table 1. DEC and DEP Annual Net Savings Results

Jurisdiction	Net per Participant Savings			Net Program Savings		
	Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
DEC	559.00	0.0987	0.0769	5,685,589	1,003.84	782.10
DEP	743.00	0.1312	0.1022	4,432,738	782.64	609.76

As part of the engineering analysis, we estimated ISRs for measures provided in the starter kit, free additional measures, and measures available for a discount. As shown in Table 2, ISRs for free measures were relatively low except for standard LEDs. The ISRs ranged from 40% for weatherstripping to around 90% for standard LEDs. We assumed an ISR of 100% for pipe wrap, as participants are often unaware of the receipt and installation of this measure, and once installed, it is unlikely to be removed. According to the survey results, auditors are not installing all the measures because some participants already have efficient measures installed and therefore do not need the starter kit measures. Additionally, some auditors did not install the measures, and participants have not had the time to install the measures themselves. Duke Energy staff also noted that participants wanted to reduce the time auditors spent in their homes due to COVID-19 concerns.

Table 2 also presents ISRs for discounted measures, which are higher than the ISRs for free measures, ranging from 80% for handheld showerheads to a high of 100% for DEP smart thermostats. This is expected, as customers tend to be more inclined to install equipment they purchased for their homes and reflects the program guidelines that auditors install all discounted equipment. Candelabra LEDs illustrate this finding well: when provided for free in the starter kit, approximately 50% were in-service at the time of our survey; however, when provided at a discount, the ISR was close to or greater than 90%.

Table 2. DEC and DEP ISR Results

Measure	DEC		DEP	
	Sample Size (n)	ISR	Sample Size (n)	ISR
Free Measures (Starter Kit and Additional)				
Standard LEDs	145	88%	98	89%
Specialty Candelabra LEDs	180	58%	78	55%
Faucet Aerators	361	53%	187	58%
Efficient Showerheads	402	41%	203	46%
Outlet Seals	93	64%	52	56%
Weather-stripping	280	39%	144	51%
Pipe Wrap[A]	N/A	100%	N/A	100%
Discounted Measures				
Specialty Globe LEDs	37	93%	20	87%
Specialty Candelabra LEDs	65	87%	38	95%
Specialty Recessed LEDs	37	83%	19	84%
Handheld Showerheads	9	83%	13	94%
Smart Thermostats	39	93%	15	100%

[A] Assumed ISR for pipe wrap is 100%.

Table 3 presents the per unit ex post deemed savings values, developed as part of our engineering analysis, for all program measures.

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Table 3. DEC and DEP Ex Post Per Unit Savings Values (Exclusive of ISRs)

Measure	DEC			DEP		
	Per Unit Energy Savings (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	Per Unit Energy Savings (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Lighting						
Standard A-line LED 9W	34.44	0.0051	0.0025	34.44	0.0051	0.0025
Candelabra LED 5W	20.26	0.0030	0.0015	20.26	0.0030	0.0015
Recessed LED 11W	44.57	0.0066	0.0032	44.57	0.0066	0.0032
Globe LED 6W	34.44	0.0051	0.0025	34.44	0.0051	0.0025
Faucet Aerators						
Kitchen Aerator	63.55	0.0028	0.0055	76.82	0.0032	0.0064
Bathroom Aerator	11.12	0.0028	0.0056	13.29	0.0032	0.0063
Other Measures						
Low-Flow Showerhead	124.63	0.0119	0.0238	160.29	0.0139	0.0278
Weatherstripping (per 17-ft. Roll)	152.59	0.0573	0.0208	171.57	0.0599	0.0263
Switch and Outlet Seal (per Seal)	0.71	0.0001	0.0003	0.82	0.0001	0.0003
Pipe Insulation (per Linear Foot)	21.37	0.0024	0.0024	25.47	0.0029	0.0029
Smart Thermostat	555.19	0.1565	0.1567	482.79	0.1226	0.1532

Note: The values above are the fuel-weighted deemed savings values the evaluation team presented in the DEC and DEP REA Program Deemed Savings Review Final Memorandum (April 12, 2023) provided to Duke Energy.

Table 4 presents the DEC and DEP engineering-based gross impacts for the various measures offered through the program, calculated by applying ISRs and ex post deemed savings values to quantities in the program tracking database. Lighting contributed the most to gross savings (>30%) followed by low-flow showerheads (>15%) and weatherstripping (>15%). Based on the engineering analysis, the average annual savings per participating household are 364 kWh and 456 kWh for DEC and DEP, respectively.

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Table 4. Ex Post Gross Impact Results for DEC and DEP from Engineering Analysis

Measure	DEC			DEP		
	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Total Lighting	1,353,870	200.33	96.97	928,525	137.39	66.50
Standard A-line LED 9W	*695,684*	*102.94*	*49.83*	*488,206*	*72.24*	*34.97*
Candelabra LED 5W	*266,720*	*39.47*	*19.10*	*189,615*	*28.06*	*13.58*
Recessed LED 11W	*188,075*	*27.83*	*13.47*	*126,874*	*18.77*	*9.09*
Globe LED 6W	*203,391*	*30.10*	*14.57*	*123,830*	*18.32*	*8.87*
Weatherstripping	605,565	227.57	82.66	520,674	181.73	79.97
Low-Flow Showerhead	580,696	55.52	111.04	531,095	45.99	91.98
Faucet Aerator (Kitchen)	345,178	15.02	30.04	265,229	11.01	22.02
Faucet Aerator (Bathroom)	82,114	20.50	41.00	65,834	15.68	31.36
Smart Thermostat	367,533	108.85	99.17	157,889	42.16	48.00
Pipe Insulation	334,676	38.18	38.18	234,440	26.74	26.74
Switch and Outlet Seal	27,802	4.15	10.40	16,413	2.22	6.75
Total for Evaluation Period	**3,697,434**	**670.13**	**509.46**	**2,720,098**	**462.94**	**373.32**
Per Household	**363.53**	**0.066**	**0.050**	**455.93**	**0.078**	**0.063**

The participant survey included questions about free-ridership (FR) and spillover (SO) to allow for the estimation of NTGRs, which are calculated as *1 – FR + SO*. We calculated FR by measure and jurisdiction and SO at the jurisdiction level. For non-kit measures (both free additional and discounted), due to smaller sample sizes, we developed measure-level FR estimates as weighted averages across the two jurisdictions. We found relatively high SO, 46% for DEC and 51% for DEP, which is consistent with the strong emphasis on energy efficiency education that this program provides. The NTGRs for all measures, excluding lighting measures, exceed 100%. Table 5 presents the NTGR results.

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Table 5. DEC and DEP FR, SO, and NTGR

NTGR Component	DEC				DEP			
	Sample Size (n)	FR	SO	NTGR	Sample Size (n)	FR	SO	NTGR
Free Measures (Starter Kit and Additional)			46%				51%	
Standard 9W LED	119	64%		82%	79	56%		95%
Candelabra LED	150	68%		78%	65	66%		85%
Low-Flow Faucet Aerator	291	10%		136%	159	11%		140%
Low-Flow Showerhead	330	12%		134%	169	17%		135%
Switch and Outlet Sealing	86	17%		129%	47	24%		127%
Weatherstripping	218	24%		122%	119	24%		127%
Pipe Wrap[A]	42	14%		132%	42	14%		137%
Discounted Measures[A]								
Specialty LED	123	45%		101%	123	45%		106%
Handheld Showerhead	20	27%		119%	20	27%		125%
Smart Thermostat	48	18%		128%	48	18%		134%

[A] Sample sizes and FR values reflect combined analysis for DEC and DEP.

When we apply the measure-level NTGRs to ex post gross impacts, we arrive at engineering analysis-based ex post net impact results (Table 6). Because the NTGRs of all measures, except LED lighting, exceed 100%, the program-level NTGR is 1.15 and 1.21 for DEC and DEP, respectively.

Table 6. Net Impact Results for DEC and DEP from Engineering Analysis

Measure	DEC			DEP		
	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Total Lighting	1,205,828	178.43	86.36	920,234	136.17	65.91
Standard A-line LED 9W	570,391	84.40	40.85	465,797	68.92	33.36
Candelabra LED 5W	240,683	35.61	17.24	188,063	27.83	13.47
Recessed LED 11W	189,655	28.06	13.58	134,803	19.95	9.65
Globe LED 6W	205,100	30.35	14.69	131,570	19.47	9.42
Weatherstripping	736,548	276.80	100.54	662,141	231.10	101.69
Low-Flow Showerhead	769,563	73.58	147.16	705,929	61.13	122.26
Faucet Aerator (Kitchen)	469,995	20.45	40.90	372,381	15.46	30.92
Faucet Aerator (Bathroom)	111,807	27.91	55.83	92,431	22.02	44.04
Smart Thermostat	471,251	139.56	127.15	210,987	56.34	64.14
Pipe Insulation	442,006	50.42	50.42	322,308	36.77	36.77
Switch and Outlet Seal	35,800	5.35	13.40	20,821	2.82	8.56
Total for Evaluation Period	**4,242,799**	**772.50**	**621.77**	**3,307,231**	**561.81**	**474.28**
Per Household	**417.15**	**0.076**	**0.061**	**554.35**	**0.094**	**0.079**

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1.3.2 DSMORE INPUTS

For planning purposes, Duke Energy requires separate per-participant savings values for the starter kit and the additional measures (free and discounted), which serve as inputs into DSMore. For all additional measures, the DSMore values are based on the engineering analysis. The estimate for the starter kit (in the first row of Table 7 and Table 8) is calculated as the per-participant value from the consumption analysis (see Table 1) minus the sum of the engineering-derived net savings for the additional measures (found in columns G, H, and I of the following two tables) multiplied by the average number of each measure type per household (found in column B). This calculation ensures that savings for the starter kit do not also include savings for the additional measures. Note that the kit savings represent a blend of those distributed in 2020 (which contained two standard LEDs) and 2021 (which contained two candelabra LEDs). Since kit savings are based on the consumption analysis, the NTGR is not applied.

Table 7. DEC Inputs for DSMore Table (Inclusive of ISRs)

A	B	Gross			F	Net		
		C	D	E		G	H	I
Measure	Average Qty per Household	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)	NTGR	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)
Starter Kit	1.0	390.96	0.0689	0.0502	N/A	390.96	0.0689	0.0502
Additional Measures								
Smart Thermostat – Electric	0.04	871.54	0.1461	0.3339	128%	1,117.49	0.1873	0.4281
Smart Thermostat – Only CAC Fuel Heated	0.04	242.60	0.1461	-	128%	311.06	0.1873	-
Specialty Candelabra LED	0.79	17.70	0.0026	0.0013	101%	17.85	0.0026	0.0013
Specialty Globe LED	0.62	32.06	0.0047	0.0023	101%	32.32	0.0048	0.0023
Specialty Recessed LED	0.50	37.04	0.0055	0.0027	101%	37.35	0.0055	0.0027
Specialty Showerhead	0.04	103.85	0.0099	0.0199	119%	123.72	0.0118	0.0237
Bathroom Aerator	0.19	5.94	0.0015	0.0030	136%	8.09	0.0020	0.0040
Pipe Wrap[A]	0.83	21.37	0.0024	0.0024	132%	28.22	0.0032	0.0032
Additional Standard LEDs	1.29	30.34	0.0045	0.0022	82%	24.88	0.0037	0.0018

[A] Quantity is in linear feet.

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Table 8. DEP Inputs for DSMore Table (Inclusive of ISRs)

A	B	Gross			F	Net		
		C	D	E		G	H	I
Measure	Average Qty per Household	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)	NTGR	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)
Starter Kit	1.0	537.68	0.0990	0.0729	N/A	537.68	0.0990	0.0729
Additional Measures								
Smart Thermostat – Electric	0.04	667.69	0.1226	0.2594	134%	892.24	0.1638	0.3467
Smart Thermostat – Only CAC Fuel Heated	0.02	216.14	0.1226	-	134%	288.83	0.1638	-
Specialty Candelabra LED	1.10	19.31	0.0029	0.0014	106%	20.52	0.0030	0.0015
Specialty Globe LED	0.69	29.87	0.0044	0.0021	106%	31.74	0.0047	0.0023
Specialty Recessed LED	0.57	37.40	0.0055	0.0027	106%	39.74	0.0059	0.0028
Specialty Showerhead	0.07	150.27	0.0130	0.0260	125%	187.15	0.0162	0.0324
Bathroom Aerator	0.28	7.69	0.0018	0.0037	140%	10.80	0.0026	0.0051
Pipe Wrap[A]	0.99	25.47	0.0029	0.0029	137%	35.01	0.0040	0.0040
Additional Standard LEDs	1.63	30.61	0.0045	0.0022	95%	29.21	0.0043	0.0021

[A] Quantity is in linear feet.

1.3.3 PROCESS FINDINGS

The following are key findings from the process analysis.

- Overall, both DEC and DEP participants are highly satisfied with the REA Program.
  - DEC and DEP respondents noted being satisfied with various program components. Notably, nearly all DEC and DEP respondents reported being satisfied with the professionalism of the auditor who visited their home, followed by the program application process, the time it took to complete the assessment, and the auditor's work quality.
  - Respondents from both jurisdictions also provided high satisfaction scores for the energy-saving recommendations and the energy assessment report.
- Program recommendations are useful and actionable, and DEC and DEP participants act on many of the recommendations they receive from the program.
  - Of the energy-saving recommendations, actions that incurred little to no additional costs – such as changing furnace fan settings, performing furnace filter maintenance, switching lights off when not in use, or washing with cold water – were conducted by most of the DEC and DEP respondents. Notably, actions that incurred significant costs, such as installing wall insulation, replacing HVAC equipment, or heat pump water heaters, were less popular among DEC and DEP respondents. While these recommendations were adopted less frequently, the adoption rate for insulation measures and HVAC equipment was greater than 20% for both DEC and DEP customers, contributing to high spillover rates. Approximately half of the DEC respondents (49%) indicated that they were made aware of other Duke home improvement programs (e.g., Smart $aver),

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compared to 62% of DEP repsondents. Increasing customer awareness of other Duke rebate programs may help increase the adoption of these higher cost measures moving forward.

- Energy bill savings, saving energy, and no-cost energy-efficient equipment are the top three drivers of REA Program participation.
- Cost is not a barrier to purchasing discounted program measures for most participants.
  - When asked why they did not purchase discounted measures through the program, DEC and DEP respondents who were aware of the discounted measures reported that they already had the discounted measures offered by the program.
- Duke Energy's program outreach (email, the Duke Energy website, and direct mail) is effective in informing participants of the program and consistent with participants' preferred modes of communication.
  - DEC and DEP respondents noted that they preferred receiving an email or direct mail from Duke Energy regarding the program. Respondents also preferred learning about the program through the Duke Energy website. These suggest frequent engagement with and trust in Duke Energy information sources as well.
- REA Program participants also learn about other Duke Energy programs through the REA Program participation.
  - The majority of DEC and DEP respondents recalled learning about the My Home Energy Report through the REA Program. Other programs respondents learned about through the REA Program include the Smart $aver and Power Manager programs.

1.4 EVALUATION RECOMMENDATIONS

Based on our evaluation activities, we present the following recommendations for consideration by Duke Energy.

Consider having program auditors provide only those starter kit measures that are installed during the inspection. Many of the starter kit measures displayed low ISRs and homeowners reported that they did not need many of the measures that were left behind with the starter kit. This issue was likely exacerbated by the COVID-19 pandemic as homeowners were interested in shorter audits. Moving forward, it would benefit the program to have auditors provide only the starter kit measures that are applicable in each participant home, as opposed to leaving measures behind for homeowner installation. This change would ensure that (1) only applicable measures are provided to each participant and (2) those measures are installed.

Continue to promote other Duke Energy programs through the REA participation process. Respondents reported learning about other Duke Energy programs, such as the My Home Energy Report and Smart Saver offerings, through the REA Program. The Smart Saver program, in particular, offers deep energy saving measures such as HVAC equipment, water heating equipment, air and duct sealing, and attic insulation, that are not currently offered through the REA Program. Building shell insulation (e.g., wall, ceiling, and floor insulation) was the most frequently cited measure when participants were asked which energy saving measures they would like to see offered by the program moving forward. Alternatively, the program could consider offering these measures at a discount directly through the REA Program. This would, however, require a follow-up visit from a program representative, which is not currently part of the program design and would increase the cost of program delivery.

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2. PROGRAM DESCRIPTION

The Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) Residential Energy Assessments (REA) Program is a home assessment program that provides customers with a customized energy report that includes low- and no-cost recommendations to help lower energy bills. Customers also receive an energy efficiency starter kit that contains two LED bulbs,[3] one low-flow showerhead, two faucet aerators (one kitchen and one bathroom), weatherstripping, and six switch and outlet seals, and a Department of Energy (DOE) booklet of energy savings tips. Through the end of 2020, the program also offered up to six free standard LEDs. In 2021, the program began offering free additional bathroom faucet aerators and free pipe wrap, as well as discounted specialty LEDs (globe, candelabra, and recessed lighting LEDs), handheld showerheads, and smart thermostats in addition to the starter kit. The energy specialist (or auditor) who performs the assessment must install purchased discounted measures, and may install any kit measures that the customers allows. The program auditors also encourage behavioral changes related to energy use and recommend higher-cost energy-saving investments to customers, such as new energy-efficient appliances.

Our evaluation includes 10,171 households in the DEC jurisdiction and 5,966 in the DEP jurisdiction that participated in the program between September 1, 2020, and August 31, 2021 ("the evaluation period").

2.1 PROGRAM DESIGN

The program targets owner-occupied, single-family residences with an electric water heater and/or electric heat or central air conditioning. The REA Program has three main components.

- The first component is the home energy assessment, branded to customers as the "Home Energy House Call." During the assessment, auditors enter participants' homes to inspect and assess energy-using equipment in the home, including their heating and cooling equipment and the state of duct and home insulation. Auditors also look for places where customers could either make an improvement to equipment (e.g., replacing older appliances) or adjust the way they use their current equipment (e.g., adjusting the setting for their furnace fan or using window shades in the summer). These recommendations are meant to steer customers toward home improvements that will help them save more energy.
- The second component is an energy efficiency starter kit that contains LED light bulbs, a low-flow showerhead, one kitchen and one bathroom faucet aerator, six switch and outlet seals, and a 17-foot roll of weatherstripping that the auditor is tasked to install free of charge, where applicable. Participants can also receive free additional bathroom faucet aerators and free pipe wrap if the home has an electric water heater. Through the end of 2020, participants were eligible to receive up to six free additional standard LEDs.
- Newly added to the program during the evaluation period is the option to purchase certain energy-efficient measures at a discount and have them installed. Discounted measures include handheld low-flow showerheads, smart thermostats, and specialty globes, candelabras, and recessed LED bulbs.[4]

Table 9 shows changes to the program, including the dates when the changes occurred.

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[3] The starter kit contained two standard LED bulbs until December 2020 but switched to two candelabra LED bulbs in January 2021.

[4] Duke Energy and the evaluation team selected the evaluation period to ensure sufficient participation of households who received the new measures.

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Table 9. Summary of Program Changes in 2020 and 2021

Timing	Program Change
August 16, 2020	Participants can choose to purchase handheld low-flow showerheads, specialty globes and candelabras, and recessed LED bulbs at a discounted cost at the time of their in-home energy audit.
October 25, 2020	Participants can choose to purchase smart thermostats at a discounted cost at the time of their in-home audit.
December 18, 2020	Program is suspended due to COVID-19 concerns.
January 1, 2021	Standard LED bulbs in energy efficiency starter kits are switched to candelabra LEDs; Duke Energy discontinues providing up to six additional standard LEDs to participants.
March 25, 2021	Suspension of program ends; program resumes in-home audits

2.2 PROGRAM IMPLEMENTATION

Duke Energy relies on a variety of marketing channels to inform customers about the REA Program. Not only does Duke Energy provide direct mailings, but it also provides business reply cards and advertises the program through Facebook postings and Duke Energy's website.

Duke Energy contracted with Franklin Energy to implement the REA Program. As noted above, the program shut down from mid-December 2020 until the end of March 2021 due to COVID-19 concerns. While the program was active, Duke Energy staff noted that program implementation was challenging because customers were less inclined to have auditors in their homes for long periods of time due to COVID-19.

2.3 PROGRAM PERFORMANCE

During the evaluation period, September 2020 to August 2021, the program served 10,171 unique households in the DEC jurisdiction and 5,966 unique households in the DEP jurisdiction. Based on the impact analysis, in the DEC jurisdiction, the program achieved average annual energy savings of 559 kWh per household and 0.0987 kW and 0.0769 kW, respectively, for summer and winter coincident demand savings. In the DEP jurisdiction the program achieved annual energy savings of 743 kWh per household and 0.1312 kW and 0.1022 kW, respectively, for summer and winter coincident demand savings.

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3. OVERVIEW OF EVALUATION ACTIVITIES

3.1 PROGRAM STAFF INTERVIEWS

In June 2021, we conducted an in-depth interview with the REA Program manager. The purpose of the interview was to gauge the current environment of, and expectations for, the REA Program, including the program's goals, successes, and challenges between September 2020 and August 2021.

3.2 PARTICIPANT SURVEY

In November 2021, Opinion Dynamics conducted a web survey with REA participants. The survey gathered data to develop ISRs and NTGRs for measures provided through the program and to support our process evaluation.

The population included the 10,171 DEC and 5,966 DEP customers who participated during the evaluation period. Of these, we were able to include 8,513 DEC and 4,871 DEP participants with valid email addresses in our sample frame and sent survey invitations to all (i.e., a census attempt). A total of 573 DEC and 307 DEP participants completed the web survey.

Participants who purchased at least one discounted measure were only asked ISR and FR questions related to the discounted measure. We asked all other participants ISR and FR questions about the measures that came in the starter kit, as well as the free additional measures. All respondents were asked the survey questions on program recommendations, SO, and demographics. The average interview length was approximately 35 minutes; the response rate was 6.9% and 6.5% for DEC and DEP, respectively. Table 10 contains a summary of the sample and survey completes.

Table 10. DEC and DEP Participant Population and Sample Summary

Program Measure Category	Population	Sample Frame		Completes	
	Number in Population (N)	Number of Participants	Percent of Population	Number of Participants (n)	Percent of Population
DEC					
Received Free Measures	10,171	6,491	64%	418	4%
Received Discounted Measures	2,395	2,022	84%	155	6%
Total [A]	**10,171**	**8,513**	**84%**	**573**	**6%**
DEP					
Received Free Measures	5,966	3,543	59%	219	4%
Received Discounted Measures	1,664	1,328	80%	88	5%
Total [A]	**5,966**	**4,871**	**82%**	**307**	**5%**

[A] All participants who received discounted measures also received free measures. As a result, the Population totals are equal to the number that received free measures. The survey, on the other hand, asked participants either about the free measures or the discounted measures but not both. As a result, the Sample Frame and Completes totals are equal to the sum of those who received free and discounted measures.

3.3 CONSUMPTION ANALYSIS

Opinion Dynamics conducted a consumption analysis to determine the net savings attributable to the REA Program for the evaluation period. We specified linear fixed effects regression (LFER) models to estimate the overall net ex post

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program savings. The fixed effect in our model is the customer, which allows us to control household factors that do not vary over time.

The consumption analysis included customers who participated in the program between October 1, 2020, to March 31, 2022 (including both the treatment group and the comparison group of future participants). A summary of the consumption analysis approach is provided in 4.1.1; a detailed description of the consumption analysis methodology is presented in APPENDIX A.

3.4 ENGINEERING ANALYSIS

The engineering analysis was used to (1) provide a ratio of kW demand to kWh energy savings, which we applied to the consumption analysis energy savings to estimate demand savings; (2) develop a DEP-to-DEC net savings ratio that was applied to the DEC consumption analysis savings to develop a comparable whole-home savings value for DEP;[5] and (3) to better understand the relative contribution of each measure to overall energy savings.

The engineering analysis consisted of two components:

- **Measure verification and development of measure-specific ISRs**: We verified the receipt, installation, and persistence of program measures and developed measure and jurisdiction-specific ISRs based on responses to the participant survey.
- **A deemed savings review of all program measures**: We reviewed measure-level savings algorithms and parameters and revised input assumptions, as needed. To develop ex post deemed energy and demand savings for each measure, we leveraged, in order of preference, program tracking data, survey results,[6] and Technical Reference Manuals (TRMs). The DEC and DEP REA Program Deemed Savings Review Final Memorandum developed for Duke Energy provides more detail on the sources and inputs used in the deemed savings review.[7] The document is available in APPENDIX B.

We calculated program-level savings by applying ISRs and ex post deemed savings values to the measure quantities tracked in the program tracking database.

[5] This was necessary because the consumption analysis did not provide reasonable results for DEP participants. This analysis is described in more detail in Section 5.3.1.
[6] We relied on demographic survey results from the prior evaluation period as only limited demographic questions were included in the survey implemented for this evaluation period.
[7] Memorandum from Opinion Dynamics to Duke Energy's EM&V Team. April 12, 2023.

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4. IMPACT EVALUATION

4.1 METHODOLOGY

As described above, the impact analysis included a consumption analysis as well as an engineering analysis.

4.1.1 CONSUMPTION ANALYSIS

Opinion Dynamics conducted a consumption analysis to determine evaluated program savings for the DEC and DEP service territories. Consumption analysis is a statistical analysis of energy consumption recorded in utility billing records. Because billing records reflect whole-building energy use, the method is well suited for studying the combined impact of the REA Program's mix of energy efficiency measures (and any behavioral changes) per home. Total program savings are estimated by examining variation among participants' monthly electricity consumption in the pre- and post-program periods, relative to the variation in a comparison group's electricity consumption during those times.

DATA CLEANING AND PREPARATION

Prior to specifying the models, we performed a thorough cleaning of the consumption and participation data. We checked data for gaps and inconsistencies as well as for sufficiency. Among other checks, we ensured the participants retained in the analysis had sufficient pre- and post-participation consumption data, participation dates were accurate, and the consumption data was free of outliers, such as bill periods with unreasonably small or unreasonably large consumption.

COMPARISON GROUP SELECTION

Incorporating a comparison group into the consumption analysis allows evaluators to control for changes in economic conditions and other non-program factors that might affect energy use during the study period. Like many other energy efficiency programs, the DEC and DEP REA Program was not designed as an experiment. As such, we leveraged a quasi-experimental approach to the evaluation by developing a comparison group of participants. There are multiple approaches to selecting a comparison group, including the use of future participants, past participants, or similar nonparticipants. When possible, it is preferable to use future program participants as a comparison group. The use of future participants—who are similar to the evaluated participants—as the comparison group allows us to effectively control for self-selection biases.

For this evaluation, we constructed a comparison group from customers who participated in the REA Program between September 1, 2021, and August 31, 2022 (i.e., future participants). We performed equivalency checks to assess the similarity of treatment and comparison groups in terms of energy consumption, weather, and housing characteristics to ensure that the comparison group could serve as a valid baseline. We performed this equivalency analysis by jurisdiction. Analysis revealed that participants in the comparison group across both DEC and DEP jurisdictions differed in terms of average daily energy consumption but were similar in terms of weather. Given these dissimilarities, we deployed distance matching algorithms to select a subset of future participants most similar to treatment participants in terms of their energy consumption in the pre-period to form a comparison group. We ran matching algorithms for each jurisdiction independently. We ran a thorough equivalency analysis between the treatment and the matched comparison customers. The two customer groups were reasonably similar in terms of energy consumption trends over time, weather, as well as other observable household characteristics such as heating and water heating system fuel type. Matched customers formed the comparison group.

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CONTROLLING FOR PARTICIPATION IN OTHER PROGRAMS

Some customers participated in other Duke Energy programs after participating in the REA Program. Including those customers in the consumption analysis would result in double counting of savings from other programs and artificially inflate the estimate of savings from the REA Program. To obtain the most accurate estimate of the effects of the REA Program, we dropped those customers who cross-participated in the following programs from the analysis: Residential Energy Efficient Products & Services, Smart $aver Residential, and Agency Assistance Portal. We used a total of 5,138 DEC and 3,025 DEP treatment participants and 2,266 DEC and 1,639 DEP comparison group participants.

MODELING

We used a Linear Fixed Effects Regression (LFER) model for this analysis. Fixed effects models capture the effect of time-invariant household-specific characteristics and are the best practice approach to modeling program savings in the industry. We specified a variety of models ranging from simple pre-post models to more complex models incorporating a variety of terms to control for known sources of variation. We specified distinct models for each jurisdiction with consideration of unique characteristics of participant populations and integration of additional terms in the models to control for variation. Consumption analyses typically include a series of additional variables to explain non-program variation in monthly energy use pre- and post-participation. Our final model specifications across all jurisdictions and states included weather (heating degree days and cooling degree days) in the model as well as monthly dummies to further control for seasonal differences in energy consumption. All models also contained a control for electricity usage, which interacted with the weather term so as not to be absorbed by the fixed effect. Our final models also contained terms for electric heat to best account for variation due to various heating fuels.

APPENDIX A. contains a detailed discussion of the consumption analysis methodology, including data cleaning steps, comparison group selection and assessment of equivalency, modeling process, and the final model specification and outputs.

Notably, consumption analysis estimates for DEP were unreasonably low in comparison to DEC, especially considering known characteristics of the DEP participant population (such as higher incidence of electric heat and higher average consumption compared to DEC participants). In addition, participants in the DEP service territory received a higher proportion of additional measures beyond energy kits, such as additional lighting, faucet aerators, and pipe insulation. Upon additional exploration and extensive additional modeling efforts, the evaluation team determined that DEP modeled savings estimates are unreasonably low and inappropriate to use in light of the known participant composition and program delivery specifics. As such, the evaluation team used the ratio of engineering net savings estimates between DEP and DEC and applied that ratio to the DEC consumption analysis results to estimate overall DEP savings estimates. The evaluation team believes this is a justifiable approach as both the engineering analysis results and the previous REA evaluation results show that DEP has higher savings levels than DEC, while the opposite was true based on consumption analysis results. APPENDIX A. contains additional detail on the evaluation team's data explorations and analysis.

4.1.2 ENGINEERING ANALYSIS

MEASURE VERIFICATION

The participant survey included questions designed to verify that participants received and installed program measures and that those measures remained in place and operational. The ISR for each measure represents the share of measures in the program tracking data that were still in service at the time of the survey, based on responses from surveyed participants who were able to provide valid responses to the ISR survey questions.

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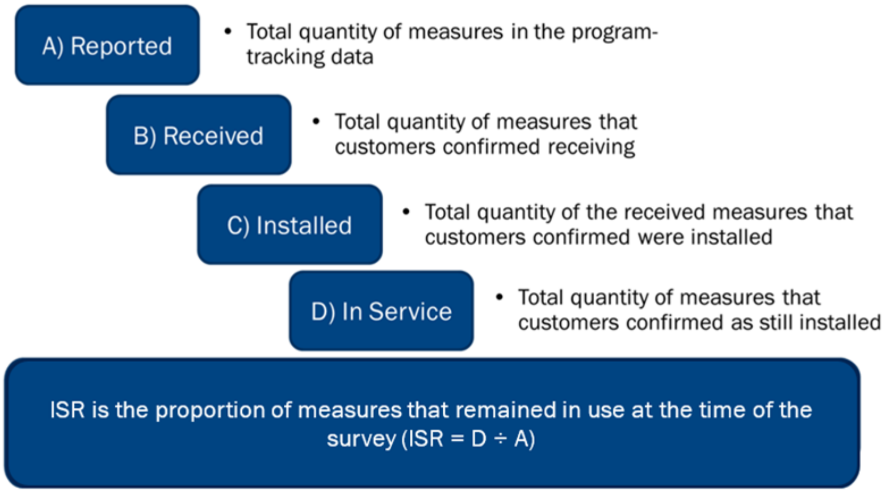
Figure 1 outlines the method for deriving the ISR for each measure. During the survey, we asked participants to confirm that they received the quantity of measures recorded in Duke Energy's program tracking data and, when necessary, to provide the correct quantity. We also asked participants to confirm the quantity of measures that were installed and remained in service at the time of the survey.

Figure 1. Installation Rate Components



Based on the survey responses, we calculated the verification, installation, and persistence rates, as well as the resulting ISR—using the equations shown in Equation 1 — for each participant and each measure they received. We then developed averages of all four rates for each measure.

Equation 1. Verification, Installation, Persistence, and In-Service Rate Equations

$$Verification\ Rate = \frac{(B) Received\ Quantity}{(A) Reported\ Quantity}$$

$$Installation\ Rate = \frac{(C) Installed\ Quantity}{(B) Received\ Quantity}$$

$$Persistence\ Rate = \frac{(D) In\ Service\ Quantity}{(C) Installed\ Quantity}$$

$$In - Service\ Rate = \frac{(D) In\ Service\ Quantity}{(A) Reported\ Quantity}$$

DEEMED SAVINGS REVIEW

To develop ex post per-unit savings for each program measure, we reviewed measure-level savings algorithms and parameters and revised input assumptions, as needed. We leveraged the following sources in our review:

- **Program tracking data:** We used program tracking data, which is the most reliable and evaluation-specific source of information, to update household characteristics such as the percentage of homes with electric heat, central cooling, and electric water heating where available.
- **Participant survey data:** Where not available from program tracking data, we used survey data to update household characteristics, such as the number of people per household. Survey data are specific to the program's participants, and therefore preferable as a source over deemed assumptions from TRMs.
- **Technical Reference Manual (TRM) assumptions:** We used algorithms and parameters from various TRMs. The preferred TRM is the Mid-Atlantic TRM V10.0. We also leveraged the Indiana TRM V2.2 (IN-TRM V2.2) and the

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Illinois TRM V10.0 (IL-TRM V10.0) if a parameter was not available from the Mid-Atlantic TRM or if one of these TRMs was deemed to have more recent or more rigorous parameters.

The *DEP and DEC Residential Energy Assessments Program Deemed Savings Review Memo* developed for Duke Energy provides detailed methods used in the deemed savings review (APPENDIX B.).

TOTAL PROGRAM GROSS SAVINGS

We developed total program gross savings, by jurisdiction, by applying the measure-specific ISRs and ex post deemed values to the measure quantities provided in the program tracking database, using the following formula:

Equation 2. Total Program Gross Savings Formula

$$Sav = \sum_{i=1}^{n} Q_{dbi} \times ISR_i \times EST_i$$

Where:

i	=	Program measures 1…n, where n = maximum number of measures in DEC and DEP REA Program
Sav	=	Total program savings
Qdbi	=	Database quantity of measure i
ISRi	=	In-service rate for measure i
ESTi	=	Per unit deemed savings estimate for measure i (kWh or kW)

Where measure savings vary based on the presence of electric heating equipment, electric water heating equipment, or central cooling equipment, our engineering team developed fuel-specific deemed values and applied them based on the space and water heating equipment specified within the program tracking database. For example, domestic hot water measures are available to all REA participants, regardless of the fuel they use to heat water in their homes. Participants with electric water heaters are assigned deemed savings values reflective of electric water heating while those with other water heating fuels are assigned zero savings. We then calculated per household savings by dividing total program savings by the number of participating households.

4.2 RESULTS

This section presents the results of the consumption and engineering analyses for the REA Program. It should be noted that the evaluation period reflects conditions in a post-COVID environment, which may impact the use of lighting and HVAC equipment and thus may affect savings.

4.2.1 CONSUMPTION ANALYSIS

This section provides average per-participant consumption analysis results, which we used to develop the annual program savings for the evaluation period. APPENDIX A. contains the complete results of the final model. Table 11 summarizes modeling results and presents key model fit metrics. The modeling results in the table are based on the DEC jurisdiction and are applied to DEC participants. As mentioned in Section 4.1.1, consumption analysis estimates for DEP were unreasonably low in comparison to DEC, especially considering known characteristics of the DEP participant population (such as higher incidence of electric heat and higher average consumption compared to DEC

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participants). As a result, the DEC consumption analysis results were also used, in conjunction with the engineering analysis results, to develop overall DEP savings estimates. The methods and inputs associated with the DEP calculations can be found in Section 5.3.1.

The final model incorporated the use of a comparison group,[8] and shows positive statistically significant participation coefficients, indicating that the model established a statistically significant relationship between participation in the program and energy consumption.

Table 11. Summary of Modeling Results

Input	Result
Modeled Treatment Participants	5,138
Average Daily Savings Estimate (kWh)	1.53
Average Daily Modeled Baseline (kWh)	43.13
Standard Error	0.11
t	72.40
P>[t]	0.00
Adjusted R-Squared	0.74
90% Confidence Interval – Lower Bound	1.35
90% Confidence Interval – Upper Bound	2.71

Table 12 contains annual savings with associated confidence bounds. The average annual per household energy savings for DEC REA participants was 559 kWh, or 3.5% of baseline consumption.

Table 12. DEC Results of Consumption Analysis Models

Modeled Treatment Participants	Average Annual Baseline Energy Consumption per Participant (kWh)	Average Per Participant Ex Post Net Annual Savings (kWh)	Average Per Participant Savings Percentage	90% Confidence Level	
				Lower	Upper
5,138	15,742	559	3.5%	491	626

The team used a combination of engineering results and the DEC consumption analysis results presented in Table 12 to calculate the average annual per household savings for DEP REA participants. We present the details of this analysis in Section 5.3.1.

Based on these results and the kW to kWh ratio from the engineering analysis (Section 4.2.3), we developed the average per participant demand savings. We then multiplied the per participant savings by the total number of participants to develop program-level energy and demand savings (Table 13).

[8] As described in the methodology section, the comparison groups consisted of matched future REA Program participants.

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Table 13. DEC and DEP Net Impact Results from Consumption Analysis

Jurisdiction	Net Participation Savings			Net Program Savings		
	Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
DEC	559.00	0.0987	0.0769	5,685,589	1,003.84	782.10
DEP	743.00	0.1312	0.1022	4,432,738	782.64	609.76

4.2.2 ENGINEERING ANALYSIS

MEASURE VERIFICATION RESULTS

The evaluation found relatively low ISRs for most of the free measures included in the starter kit and free additional measures, except for standard LEDs (Table 14 and Table 15). We did not calculate verification rates for low-flow showerheads, weatherstripping, and outlet seals because starter kits include a fixed number of these measures and we assumed each participant received a starter kit (i.e., a verification rate of 100%). Additionally, we assumed an ISR of 100% for pipe wrap, as participants are often not aware of the receipt and installation of this measure and once installed, it is unlikely to be removed.

Based on responses to the participant survey, auditors do not always install starter kit measures during the assessments. This may be because starter kit equipment did not fit, participants already had efficient measures installed, and/or participants wanted to reduce time auditors spent in their homes due to COVID-19 concerns. The following are specific factors that contributed to the low ISRs for non-lighting measures:

- Faucet aerators: Respondents reported that they already had faucet aerators or that they have specialty faucets that are not compatible with the aerators provided by the program.
- Low-flow showerheads: Respondents reported that they were already using efficient showerheads, while others simply did not like the showerheads provided by the program.
- Switch and outlet seals: Respondents indicated that they either have not gotten around to installing them, they forgot, or do not see the need to install them.
- Weatherstripping: Respondents gave similar reasons as they gave for switch and outlet seals: they either have not gotten around to installing it, they forgot, or they do not see the need for it. Others reported that they already had weatherstripping installed or did not need the full amount provided by the program.

We found higher ISRs for discounted measures, which is expected since there is a high likelihood a participant would install measures they had to purchase. Candelabra LEDs illustrate this finding well: When provided for free in the starter kit, only 50% were in-service at the time of our survey; however, when provided at a discount, the ISR was around 90%.

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Table 14. DEC Measure-Level ISR Results

Measure	n	Verification Rate[A]	Installation Rate	Persistence Rate	In-Service Rate
Free Measures (Starter Kit and Additional)					
Standard A-line LED 9W (2020)[B]	145	99%	91%	98%	88%
Candelabra LED 5W (2021)	180	N/A	59%	98%	58%
Low-Flow Showerhead	402	N/A	46%	90%	41%
Faucet Aerator (Kitchen and bathroom)[B]	361	94%	59%	97%	53%
Switch/Outlet Seal	93	N/A	64%	100%	64%
Weather Stripping	280	N/A	43%	91%	39%
Pipe Insulation[C]	N/A	N/A	N/A	N/A	100%[C]
Discounted Measures					
Specialty Globe LED	37	98%	97%	98%	93%
Specialty Candelabra LED	65	98%	91%	98%	87%
Specialty Recessed LED	37	88%	96%	98%	83%
Handheld Showerhead[D]	9	100%	92%	91%	83%
Smart Thermostat	39	100%	100%	93%	93%

[A] We did not estimate a verification rate for measures only provided through the starter kit, assuming every participant received a starter kit (i.e., the assumed verification rate is 100%).

[B] Includes both kit measures and additional free measures.

[C] Assumed ISR for pipe wrap is 100%.

[D] The estimated ISR is similar to values in the IL TRM and IN TRM so we use it despite the small sample size. The Mid-Atlantic TRM only has a direct install measure, i.e., no ISR.

Table 15. DEP Measure-Level ISR Results

Measure	n	Verification Rate[A]	Installation Rate	Persistence Rate	In-Service Rate
Free Measures (Starter Kit and Additional)					
Standard A-line LED 9W (2020)[B]	98	99%	90%	99%	89%
Candelabra LED 5W (2021)	78	N/A	55%	100%	55%
Low Flow Showerhead	203	N/A	52%	89%	46%
Faucet Aerator (Kitchen and Bathroom)[B]	187	97%	62%	96%	58%
Switch/Outlet Seal	52	N/A	56%	100%	56%
Weather Stripping	144	N/A	52%	97%	51%
Pipe Insulation[C]	N/A	N/A	N/A	N/A	100%
Discounted Measures					
Specialty Globe LED	20	93%	94%	100%	87%
Specialty Candelabra LED	38	99%	97%	100%	95%
Specialty Recessed LED	19	94%	90%	100%	84%
Handheld Showerhead	13	94%	100%	100%	94%
Smart Thermostat	15	100%	100%	100%	100%

[A] We did not estimate a verification rate for measures only provided through the starter kit, assuming every participant received a starter kit (i.e., the assumed verification rate is 100%).

[B] Includes both kit measures and additional free measures.

[C] Assumed ISR for pipe wrap is 100%.

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EX POST DEEMED SAVINGS ESTIMATES

Table 16 provides the estimated gross per-unit energy and demand savings for all measures installed through the program. The values presented in the table below represent the fuel-weighted deemed values provided in the DEC and DEP REA Program Deemed Savings Review Memorandum provided to Duke Energy. As described in Section 3.4, we used measure-level savings assumptions based on program tracking data, survey results, and TRMs, in that order of source preference.

Table 16. Ex Post Deemed Energy Savings and Peak Demand Reduction Values (Exclusive of ISRs) for DEC and DEP

Measure	DEC			DEP		
	Per Unit Energy Savings (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	Per Unit Energy Savings (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Lighting						
Standard A-line LED 9W	34.44	0.0051	0.0025	34.44	0.0051	0.0025
Candelabra LED 5W	20.26	0.0030	0.0015	20.26	0.0030	0.0015
Recessed LED 11W	44.57	0.0066	0.0032	44.57	0.0066	0.0032
Globe LED 6W	34.44	0.0051	0.0025	34.44	0.0051	0.0025
Faucet Aerators						
Kitchen Aerator	63.55	0.0028	0.0055	76.82	0.0032	0.0064
Bathroom Aerator	11.12	0.0028	0.0056	13.29	0.0032	0.0063
Other Measures						
Low-Flow Showerhead	124.63	0.0119	0.0238	160.29	0.0139	0.0278
Weatherstripping (per 17-ft. Roll)	152.59	0.0573	0.0208	171.57	0.0599	0.0263
Switch and Outlet Seal (per Seal)	0.71	0.0001	0.0003	0.82	0.0001	0.0003
Pipe Insulation (per Linear Foot)	21.37	0.0024	0.0024	25.47	0.0029	0.0029
Smart Thermostat	555.19	0.1565	0.1567	482.79	0.1226	0.1532

Note: The values above are the fuel-weighted deemed savings values the evaluation team presented in the DEC and DEP REA Program Deemed Savings Review Final Memorandum (April 12, 2023) provided to Duke Energy.

TOTAL PROGRAM SAVINGS

The evaluation team calculated total program savings by applying the deemed savings values and ISRs summarized above to measure quantities tracked in the program database.[9] Table 17 presents total gross program energy and demand savings by measure for the evaluation period. As shown, lighting contributed most to program savings (>30%) followed by low-flow showerheads (>15%) and weatherstripping (>15%). On average, household annual savings are 364 kWh and 456 kWh for DEC and DEP customers, respectively.

[9] Note that the ex post analysis applies fuel-type specific deemed savings values, rather than the fuel-weighted values presented in Table 16.

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Table 17. Engineering Analysis Gross Impact Results for DEC and DEP

Measure	DEC			DEP		
	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Total Lighting	1,353,870	200.33	96.97	928,525	137.39	66.50
Standard A-line LED 9W	*695,684*	*102.94*	*49.83*	*488,206*	*72.24*	*34.97*
Candelabra LED 5W	*266,720*	*39.47*	*19.10*	*189,615*	*28.06*	*13.58*
Recessed LED 11W	*188,075*	*27.83*	*13.47*	*126,874*	*18.77*	*9.09*
Globe LED 6W	*203,391*	*30.10*	*14.57*	*123,830*	*18.32*	*8.87*
Weatherstripping	605,565	227.57	82.66	*520,674*	*181.73*	*79.97*
Low-Flow Showerhead	580,696	55.52	111.04	531,095	45.99	91.98
Faucet Aerator (Kitchen)	345,178	15.02	30.04	265,229	11.01	22.02
Faucet Aerator (Bathroom)	82,114	20.50	41.00	65,834	15.68	31.36
Smart Thermostat	367,533	108.85	99.17	157,889	42.16	48.00
Pipe Insulation	334,676	38.18	38.18	234,440	26.74	26.74
Switch and Outlet Seal	27,802	4.15	10.40	16,413	2.22	6.75
Total for Evaluation Period	**3,697,434**	**670.13**	**509.46**	**2,720,098**	**462.94**	**373.32**
Per Household	**363.53**	**0.066**	**0.050**	**455.93**	**0.078**	**0.063**

The above table presents the total and per-participant engineering gross impacts, including all starter kit measures, free additional measures, and measures purchased at a discount. In Table 18 we show the estimated per household energy and demand savings for the starter kits currently available through the program, free additional measures, and discounted measures. As shown in the tables, the starter kit accounted for approximately 55% of per household savings, while free and discounted measures accounted for nearly 20% and 25%, respectively.

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Table 18. Engineering Analysis Gross Impact Results per Household (Inclusive of ISRs) for DEC and DEP

Measure	DEC			DEP		
	Energy Savings (kWh)	Summer Peak Demand (kW)	Winter Peak Demand (kW)	Energy Savings (kWh)	Summer Peak Demand (kW)	Winter Peak Demand (kW)
Kit Measures						
Standard 9W LED	29.12	0.0043	0.0021	32.07	0.0047	0.0023
Candelabra LED	12.24	0.0018	0.0009	10.64	0.0016	0.0008
Kitchen Aerator	33.94	0.0015	0.0030	44.46	0.0018	0.0037
Bathroom Aerator	5.94	0.0015	0.0030	7.69	0.0018	0.0037
Low-Flow Showerhead	51.46	0.0049	0.0098	74.22	0.0064	0.0129
Switch and Outlet Sealing	2.73	0.0004	0.0010	2.75	0.0004	0.0011
Weatherstripping	59.54	0.0224	0.0081	87.27	0.0305	0.0134
Total Kit Gross Estimate	**194.97**	**0.0368**	**0.0279**	**259.11**	**0.0473**	**0.0378**
Free Additional Measures						
Standard 9W LED	39.28	0.0058	0.0028	49.76	0.0074	0.0036
Low-Flow Faucet Aerator	2.13	0.0005	0.0011	3.34	0.0008	0.0016
Pipe Wrap	32.90	0.0038	0.0038	39.30	0.0045	0.0045
Total for Free Additional Measures	**74.32**	**0.0101**	**0.0076**	**92.40**	**0.0126**	**0.0096**
Discounted Measures						
Specialty LED	52.48	0.0078	0.0038	63.17	0.0093	0.0045
Handheld Showerhead	5.63	0.0005	0.0011	14.80	0.0013	0.0026
Smart Thermostat	36.14	0.0107	0.0097	26.46	0.0071	0.0080
Total for Discounted Measures	**94.24**	**0.0190**	**0.0146**	**104.43**	**0.0177**	**0.0151**
Total for All Measures	**363.53**	**0.0659**	**0.0501**	**455.93**	**0.0776**	**0.0626**

4.2.3 DEMAND-TO-ENERGY RATIOS

Using the energy and demand savings from the engineering analysis for DEC and DEP (Table 17 and Table 18, respectively), we calculated kW-per-kWh savings ratios for both summer and winter peak demand, separately for both jurisdictions and combined. We used the combined ratios to derive the estimated demand savings associated with the energy savings calculated from the consumption analysis for both jurisdictions, shown in Table 19.

Table 19. Engineering Demand-to-Energy Ratios

Jurisdiction	Total Gross Energy Savings (kWh)	Summer Coincident Peak Savings (kW)	Winter Coincident Peak Savings (kW)	Summer Ratio Multiplier (summer demand/energy savings)	Winter Ratio Multiplier (winter demand/energy savings)
DEC	3,697,434	670.13	509.46	0.000181	0.000138
DEP	2,720,098	462.94	373.32	0.000170	0.000137
Combined	**6,417,532**	**1,133.07**	**882.78**	**0.000177**	**0.000138**

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4.2.4 DSMORE INPUTS

For planning purposes, Duke Energy requires separate per-participant savings values for the starter kit and the additional measures (free and discounted), which serve as inputs into DSMore. For all additional measures, the DSMore values are based on the engineering analysis (see Table 17). The estimate for the starter kit (in the first row of the following two tables) is calculated as the per-participant value from the consumption analysis (see Table 13) minus the sum of the engineering-derived net savings per measure (columns G, H, and I of the following two tables) multiplied by the average number of each measure type per household (found in column B). This calculation ensures that savings for the starter kit do not include savings for the additional measures. Note that the kit savings represent a blend of those distributed in 2020 (which contained two standard LEDs) and 2021 (which contained two candelabra LEDs). Since kit savings are based on the consumption analysis, the NTGR is not applied.

Table 20. DEC Inputs for DSMore Table

A	B	Gross			F	Net		
		C	D	E		G	H	I
Measure	Average Qty per Household	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)	NTGR	kWh	Summer Peak Savings (kW)	Winter Peak Savings (kW)
Starter Kit	1.0	390.96	0.0689	0.0502	N/A	390.96	0.0689	0.0502
Additional Measures								
Smart Thermostat – Electric	0.04	871.54	0.1461	0.3339	128%	1,117.49	0.1873	0.4281
Smart Thermostat – Only CAC Fuel Heated	0.04	242.60	0.1461	-	128%	311.06	0.1873	-
Specialty Candelabra LED	0.79	17.70	0.0026	0.0013	101%	17.85	0.0026	0.0013
Specialty Globe LED	0.62	32.06	0.0047	0.0023	101%	32.32	0.0048	0.0023
Specialty Recessed LED	0.50	37.04	0.0055	0.0027	101%	37.35	0.0055	0.0027
Specialty Showerhead	0.04	103.85	0.0099	0.0199	119%	123.72	0.0118	0.0237
Bathroom Aerator	0.19	5.94	0.0015	0.0030	136%	8.09	0.0020	0.0040
Pipe Wrap[A]	0.83	21.37	0.0024	0.0024	132%	28.22	0.0032	0.0032
Additional Standard LEDs	1.29	30.34	0.0045	0.0022	82%	24.88	0.0037	0.0018

[A] Quantity is linear feet

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Table 21. DEP Inputs for DSMore Table

A	B	Gross			F	Net		
		C	D	E		G	H	I
Measure	**Average Qty per Household**	**kWh**	**Summer Peak Savings (kW)**	**Winter Peak Savings (kW)**	**NTGR**	**kWh**	**Summer Peak Savings (kW)**	**Winter Peak Savings (kW)**
Starter Kit	1.0	537.68	0.0990	0.0729	N/A	537.68	0.0990	0.0729
Additional Measures								
Smart Thermostat – Electric	0.04	667.69	0.1226	0.2594	134%	892.24	0.1638	0.3467
Smart Thermostat – Only CAC Fuel Heated	0.02	216.14	0.1226	-	134%	288.83	0.1638	-
Specialty Candelabra LED	1.10	19.31	0.0029	0.0014	106%	20.52	0.0030	0.0015
Specialty Globe LED	0.69	29.87	0.0044	0.0021	106%	31.74	0.0047	0.0023
Specialty Recessed LED	0.57	37.40	0.0055	0.0027	106%	39.74	0.0059	0.0028
Specialty Showerhead	0.07	150.27	0.0130	0.0260	125%	187.15	0.0162	0.0324
Bathroom Aerator	0.28	7.69	0.0018	0.0037	140%	10.80	0.0026	0.0051
Pipe Wrap[A]	0.99	25.47	0.0029	0.0029	137%	35.01	0.0040	0.0040
Additional Standard LEDs	1.63	30.61	0.0045	0.0022	95%	29.21	0.0043	0.0021

[A] Quantity is linear feet

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5. NET-TO-GROSS ANALYSIS

5.1 METHODOLOGY

Our net-to-gross (NTG) analysis includes consideration of measure-level FR and jurisdiction-level participant SO. The NTGR is calculated as follows:

Equation 3. NTGR Formula

$$NTGR_{measure} = 1 - FR_{measure} + SO_{jurisdiction}$$

The NTGR represents the portion of the gross energy savings associated with a program-supported measure that would not have been realized in the absence of the program. In other words, the NTGR represents the share of verified savings that are attributable to the program.

To develop NTGRs for the various program measures, the participant survey included measure-level FR questions and a program-level SO module. We calculated FR by measure and jurisdiction and SO at the jurisdiction level. For kit measures we applied the unique measure-level FR values that were specific to each jurisdiction. For non-kit measures (both free additional and discounted), due to smaller sample sizes, we developed measure-level FR estimates as weighted averages across the two jurisdictions. APPENDIX C. provides a detailed overview of the FR and SO algorithms.

5.1.1 FREE-RIDERSHIP

Free-riders are program participants who would have paid for an assessment or installed energy efficiency products on their own, without the program. FR scores represent the percentage of savings that would have been achieved in the absence of the program. We categorized participants who reported that they **would not** have installed a measure without the program as 0% free-riders and participants who **would** have installed the measure without the program as 100% free-riders. We assigned partial scores to customers who had plans to install the measure, but the program had at least some influence over that decision, including in terms of timing (i.e., the program accelerated the installation) or quantity (i.e., the program led to the installation of additional measures). We asked questions for each program measure, to enable us to develop measure-level FR estimates. The survey questions measured the following areas of program influence:

- **Influence on installation:** We asked participants about the likelihood that they would have installed each starter kit measure if they had not received it with the assessment.
- **Influence on timing:** We asked participants when they would have installed the measure on their own, whether that would have been around the same time, within six months, within a year, or longer.
- **Influence on quantity:** We asked participants whether they would have purchased the same quantity, more, or fewer on their own, without receiving them free through the program.

As part of the FR survey module, we included follow-up questions to check participant responses for consistency.

The team developed a single set of weighted FR values, covering both DEC and DEP jurisdictions, for all non-kit measures. These measures include pipe wrap, specialty LEDs, handheld showerheads, and smart thermostats. The DEC and DEP results were weighted based on the measure-level quantities found in the program tracking data for each jurisdiction. The FR values for non-kit measures were combined for DEC and DEP due to the small sample sizes associated with these measures within the FR analysis for each jurisdiction.

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5.1.2 PARTICIPANT SPILLOVER

Participant SO represents energy savings from additional actions (expressed as a percentage of total program savings) that resulted from program participation, but that did not receive program financial support and is not tracked in program databases. While SO can result from a variety of measures, it is not possible to ask about all potential SO measures in a survey due to the need to limit its length. Thus, we chose to focus on actions that participants would reasonably take following their program participation and would do so without additional program support.

The participant survey included a series of questions to assess overall SO among program participants. To qualify for program-induced SO, we asked two main questions:

- Did the participant make any additional improvements to reduce household energy consumption since participating in the program?
- If the respondent indicated having made additional improvements: How would the participant rate the influence their experience with the program had on their decision to make these improvements, on a scale from 0 to 10?

We asked participants to rate the degree to which the program influenced their action and to provide a rationale for their rating. We attributed SO to all respondents who gave a program influence score of seven or higher. These respondents were asked a series of follow-up questions to assess the efficiency of measures.

To estimate the SO rate, we estimated savings for each SO measure, by jurisdiction, using engineering algorithms and assumptions. We determined the jurisdiction-level SO rate by dividing the sum of measure-level SO savings by the evaluated gross savings achieved by the sample of participants who received SO questions.

Equation 4. Spillover Formula

$$Spillover\ Rate = \frac{Spillover\ Savings}{Evaluated\ Gross\ Savings\ in\ the\ Respondent\ Sample}$$

5.2 NET-TO-GROSS RESULTS

5.2.1 FREE-RIDERSHIP

Based on responses to FR questions in our participant survey, we calculated FR scores for respondents who reported installing the measure. Table 22 shows the FR results for free and discounted measures, respectively. As these tables show, FR is low for all measures except for lighting. This means that most of the verified gross savings would not have occurred without the program.

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Table 22. DEC and DEP FR Results

Measures	DEC		DEP	
	Sample Size (n)	Estimate	Sample Size (n)	Estimate
Free Measures (Starter Kit and Additional)				
Standard LEDs	119	64%	79	56%
Specialty Candelabra LEDs	150	68%	65	66%
Faucet Aerators	291	10%	159	11%
Low Flow Showerheads	330	12%	169	17%
Outlet Seals	86	17%	47	24%
Weather-stripping[A]	218	24%	119	24%
Pipe Wrap	42	14%	42	14%
Discounted Measures[A]				
Specialty LEDs	123	45%	123	45%
Handheld Showerheads	20	27%	20	27%
Smart Thermostats	48	18%	48	18%

[A] Sample sizes and FR values reflect combined analysis for DEC and DEP.

5.2.2 PARTICIPANT SPILLOVER

Based on responses to the participant survey, approximately 26% of participants (225 of 880 respondents) installed qualifying spillover (SO) measures influenced by their program participation. Nearly two-thirds (65%) of participants with eligible SO measures were DEC customers, with the remaining 35% being DEP customers. Table 23 summarizes the types and quantities of reported SO measures and their estimated energy savings for DEC and DEP, respectively. Based on these findings, we estimated a program-level SO rate of 46% for DEC and 51% for DEP, which is the quotient of the total SO savings estimated for survey respondents and the total ex post gross engineering savings of all survey respondents.[10]

[10] Total engineering savings of participants is calculated by multiplying the average engineering savings per home by the total number of survey respondents. Note numbers are rounded.

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Table 23. Engineering Spillover Summary

Measure Type	DEC		DEP		Source of per Unit Savings
	Measure Quantity	Energy Savings (kWh)	Measure Quantity	Energy Savings (kWh)	
Central Air Conditioner	30	32,878	21	24,440	Mid-Atlantic TRM V10.0
LEDs	688	23,698	426	14,664	DEC REA Deemed Savings Review
Clothes Washer	24	7,989	21	7,217	Mid-Atlantic TRM V10.0; Illinois TRM V10.0
Weatherstripping	60	8,750	31	5,424	DEC REA Deemed Savings Review
Low-Flow Showerhead	29	6,711	16	3,996	DEC REA Deemed Savings Review
Heat Pump Water Heater	-	-	2	3,820	Mid-Atlantic TRM V10.0
Windows	55	4,434	12	1,449	Illinois TRM V10.0
Duct Sealing	1	2,950	1	2,804	DEC LI Weatherization Deemed Savings Review
Attic Insulation	3,671	3,740	963	507	DEC LI Weatherization Deemed Savings Review
Refrigerator	36	1,830	24	1,220	Mid-Atlantic TRM V10.0
Faucet Aerators	21	1,456	22	1,545	DEC REA Deemed Savings Review
Advanced Thermostat	2	1,194	2	884	DEC REA Deemed Savings Review
Crawlspace Insulation	113	1,529	-	-	Illinois TRM V10.0
Dishwasher	17	629	13	481	Mid-Atlantic TRM V10.0
Freezer	8	250	11	344	Mid-Atlantic TRM V10.0
Duct Insulation	-	-	1	556	DEC LI Weatherization Deemed Savings Review
Clothes Dryer	4	407	1	102	Mid-Atlantic TRM V10.0
Water Heater Tank Wrap	1	235	1	235	Mid-Atlantic TRM V10.0
Room Air Conditioner	8	186	8	186	Mid-Atlantic TRM V10.0
Outlet Gasket Seal	172	103	355	256	DEC REA Deemed Savings Review
Spillover Savings		**98,970**		**70,128**	
Ex Post Gross Program Savings		**216,473**		**137,162**	
Spillover %		**46%**		**51%**	

Table 24 shows FR and SO estimates along with NTGRs for measures provided through the program. Aside from lighting measures, the NTGRs are greater than 100%.

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Table 24. Measure-Level FR, SO, and NTGR for DEC and DEP

NTGR Component	DEC				DEP			
	Sample Size (n)	FR	SO	NTGR	Sample Size (n)	FR	SO	NTGR
Free Measures (Starter Kit and Additional)								
Standard 9W LED	119	64%		82%	79	56%		95%
Candelabra LED	150	68%		78%	65	66%		85%
Faucet Aerator	291	10%		136%	159	11%		140%
Low-Flow Showerhead	330	12%		134%	169	17%		135%
Switch and Outlet Sealing	86	17%	46%	129%	47	24%	51%	127%
Weatherstripping	218	24%		122%	119	24%		127%
Pipe Wrap[A]	42	14%		132%	42	14%		137%
Discounted Measures[A]								
Specialty LED	123	45%		101%	123	45%		106%
Handheld Showerhead	20	27%		119%	20	27%		125%
Smart Thermostat	48	18%		128%	48	18%		134%

[A] Sample sizes and FR values reflect combined analysis for DEC and DEP.

5.3 NET IMPACT RESULTS

Table 25 shows estimated net energy and demand savings for each measure offered by the DEC and DEP REA Program. Notably, lighting, low-flow showerheads, and weatherstripping contributed the largest share to energy and demand savings; water heater pipe insulation and switch and outlet seals contributed the least.

Table 25. Engineering Analysis Net Impact Results for DEC and DEP

Measure	DEC			DEP		
	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	kWh	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
Total Lighting	1,205,828	178.43	86.36	920,234	136.17	65.91
Standard A-line LED 9W	570,391	84.40	40.85	465,797	68.92	33.36
Candelabra LED 5W	240,683	35.61	17.24	188,063	27.83	13.47
Recessed LED 11W	189,655	28.06	13.58	134,803	19.95	9.65
Globe LED 6W	205,100	30.35	14.69	131,570	19.47	9.42
Weatherstripping	736,548	276.80	100.54	662,141	231.10	101.69
Low-Flow Showerhead	769,563	73.58	147.16	705,929	61.13	122.26
Faucet Aerator (Kitchen)	469,995	20.45	40.90	372,381	15.46	30.92
Faucet Aerator (Bathroom)	111,807	27.91	55.83	92,431	22.02	44.04
Smart Thermostat	471,251	139.56	127.15	210,987	56.34	64.14
Pipe Insulation	442,006	50.42	50.42	322,308	36.77	36.77
Switch and Outlet Seal	35,800	5.35	13.40	20,821	2.82	8.56
Total for Evaluation Period	**4,242,799**	**772.50**	**621.77**	**3,307,231**	**561.81**	**474.28**
Per Household	**417.15**	**0.076**	**0.061**	**554.35**	**0.094**	**0.079**

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5.3.1 DEP IMPACT RESULTS

As noted above, consumption analysis estimates for DEP were unreasonably low in comparison to DEC, especially considering known characteristics of the DEP participant population (such as higher incidence of electric heat, higher average consumption, and a higher proportion of additional measures, compared to DEC participants). As a result, the DEC consumption analysis results were used in conjunction with the engineering analysis net savings results to develop overall DEP per participant savings estimates.

Specifically, the evaluation team used the DEP-to-DEC ratio of per household engineering net savings and applied that ratio to the DEC per household consumption analysis results to estimate per household savings for DEP. The evaluation team believes this is a justifiable approach as the engineering analysis results show that DEP achieved higher per household gross savings than DEC (455.93 kWh versus 363.53 kWh; see Table 4). These results are consistent with previous REA evaluation results, which also show that DEP achieved higher per household gross savings levels than DEC, at 458.2 kWh versus 376.9 kWh,[11] while the consumption analysis results show the opposite. The values used for this analysis, the resulting ratio of engineering savings estimates between DEC and DEP, and the average annual per household savings for DEP participants are listed in Table 26.

Table 26. DEP per Participant Savings Calculations

DEP per Participant Savings Estimate	Values
DEC per Participant Net Savings (kWh) – Engineering Analysis (A)	417.15
DEP per Participant Net Savings (kWh) – Engineering Analysis (B)	554.35
DEP:DEP Savings Ratio (C=B/A)	1.33
DEC per Participant Savings (kWh) – Consumption Analysis (D)	559.00
DEP per Participant Savings (kWh) (E=C*D)	743.00

[11] Source: Opinion Dynamics Corporation, *Duke Energy Carolinas Residential Energy Assessments Program Evaluation Report – Final* (2018).

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6. PROCESS ANALYSIS

As part of the evaluation, the evaluation team conducted a web survey to gather information from DEC and DEP REA Program participants regarding their experience with the program. The web survey gathered information used to answer the following research questions:

- What proportion of participants are choosing to install smart thermostats, enhanced lighting (e.g., specialty globes and candelabras, etc.), handheld low-flow showerheads, and/or opt for blower door tests for a rebated cost?
- What marketing channels are most effective in motivating customers to participate in the REA Program?
- Are customers satisfied with the participation process and program measures?
- What are the challenges associated with program participation?
- Do participants find the assessment recommendations useful and actionable?
- Does the REA Program inform eligible customers of other energy-saving opportunities and are they channeled into other Duke Energy programs?
- What kind of behavioral changes do participants make following the assessment?
- What are the most successful components of the program? What improvements can be made to the program's design and implementation?

This section details the findings from the participant survey.

6.1 PROGRAM PARTICIPATION

During the evaluation period, September 2020 through August 2021, 10,171 unique households in the DEC jurisdiction and 5,996 households in the DEP jurisdiction participated in the REA Program. Each participating household received one starter kit, while 1,021 DEC and 869 DEP received at least one free additional low-flow faucet aerator and 1,357 DEC and 985 DEP households received pipe wrap. In addition, 2,638 DEC and 1,886 DEP households received at least one free additional standard LED.

Apart from starter kit and free additional LEDs, pipe wrap and low-flow faucet aerators, 24% of DEC participants and 28% of DEP participants purchased at least one discounted measure through the REA Program. As shown in Table 27, the majority of those who purchased discounted measures purchased specialty LEDs. Fewer than 10% of both DEC and DEP participants as purchased handheld showerheads and/or smart thermostats.

Table 27. Proportion of Participants with Discounted Measures

Measure	Percent DEC	Percent DEP
Any Discounted Measure	**24%**	**28%**
Specialty LED	18%	23%
Specialty Globe LED	*7%*	*8%*
Specialty Candelabra LED	*11%*	*15%*
Specialty Recessed LED	*6%*	*7%*
Handheld Showerhead	3%	5%
Smart Thermostat	6%	4%

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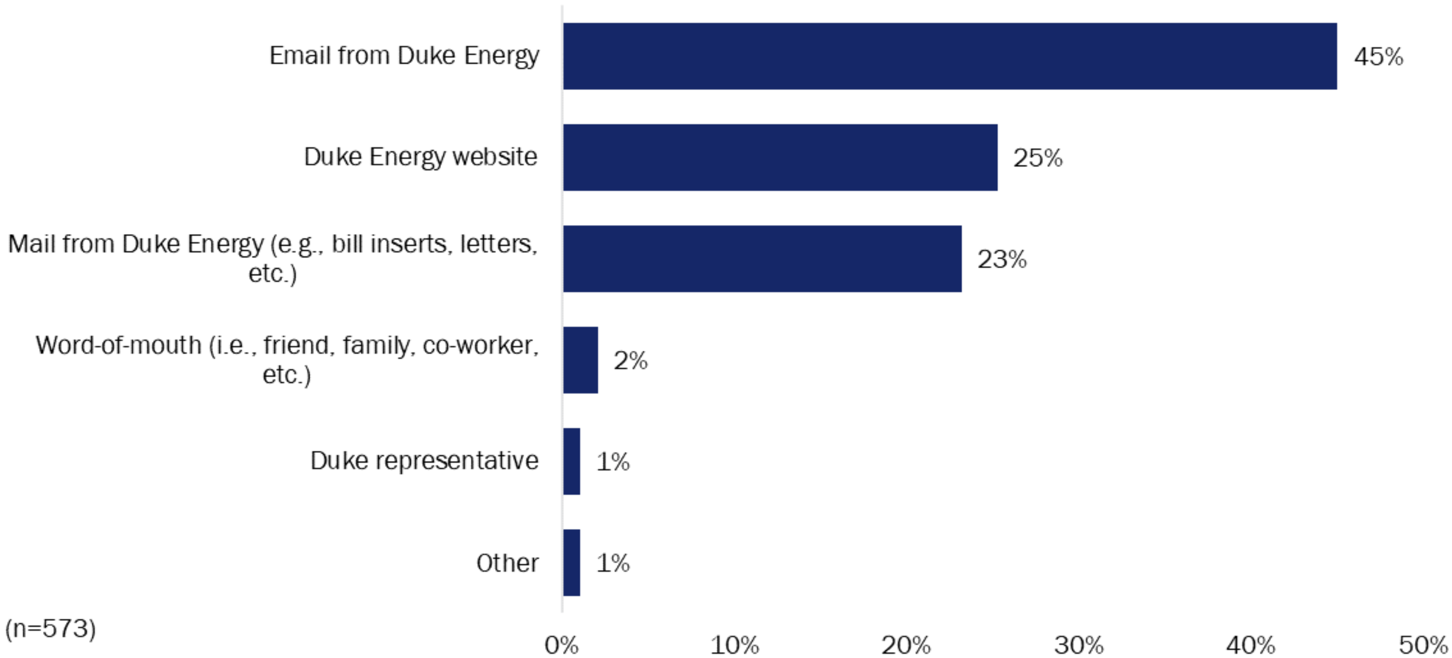
6.2 PROGRAM AWARENESS

In creating awareness among DEC and DEP customers regarding the REA Program, survey results suggest that Duke Energy branded information sources such as email, direct mail, and the Duke Energy website were effective, and perhaps, more trusted information and communication sources compared to other more general sources of information and modes of communication. The primary sources of information regarding the REA Program for surveyed DEC participants were email (45%), the Duke Energy website (25%), and direct mail from Duke Energy (23%). Digital media sources such as social media and Pandora radio were cited less frequently as forms of media where respondents learned about the program (Figure 2).

Figure 2. DEC Primary Source of Information on REA Program



Similarly, DEP respondents reported learning about the REA Program primarily through an email from Duke Energy (45%). Direct mail (26%) and the Duke Energy website (22%) were also identified as primary sources of information regarding the REA Program, as shown in Figure 3.

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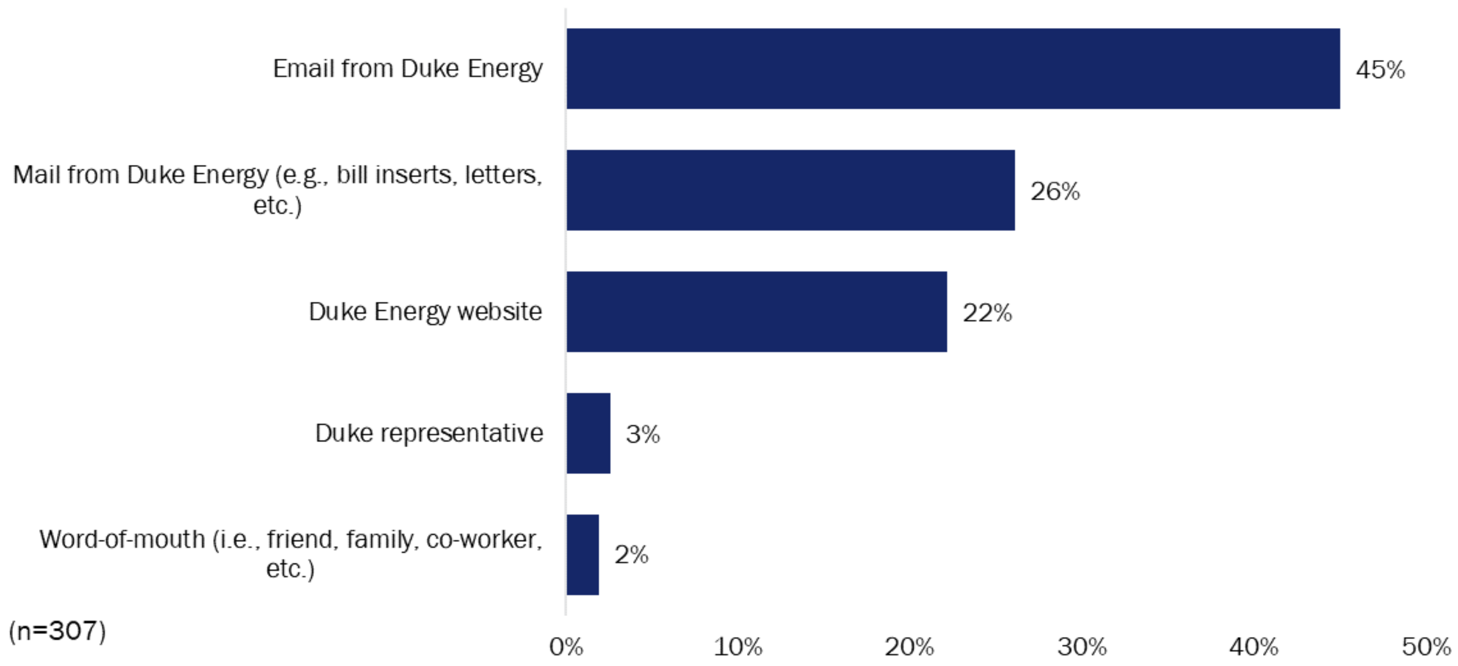
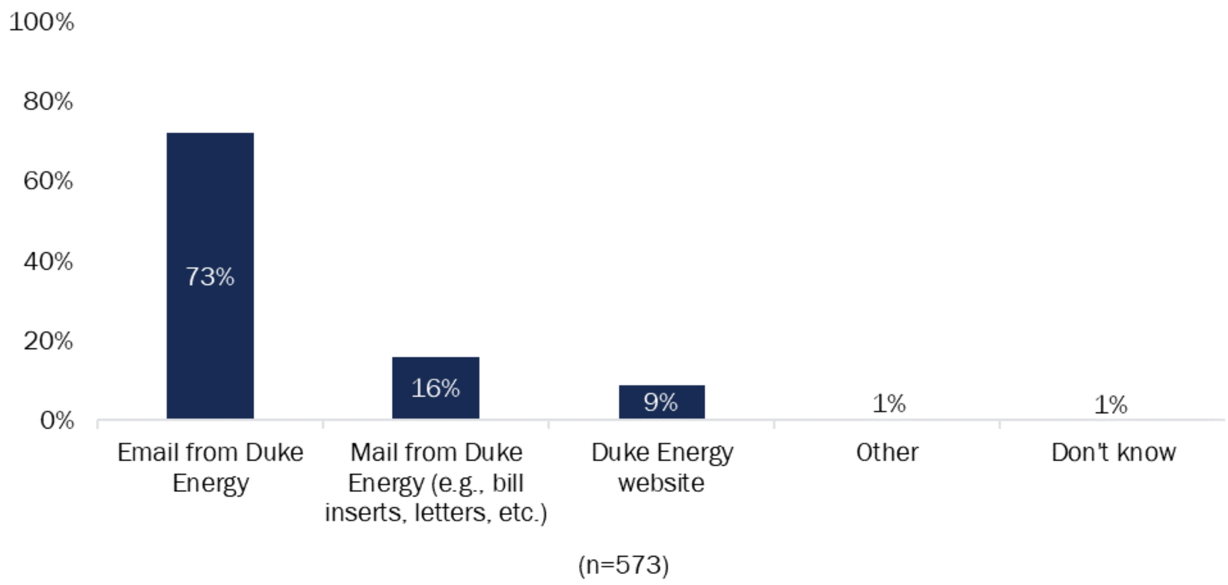
Figure 3. DEP Primary Source of Information on REA Program



The findings regarding primary program information sources are consistent with DEC and DEP respondents' preferred forms of communication. Figure 4 shows the most preferred forms of communication regarding the REA Program among DEC respondents are email (73%), direct mail (16%), and the Duke Energy website (9%).

Figure 4. DEC Preferred Forms of Communication



The same is true for DEP respondents, where email (75%), direct mail (16%), and the Duke Energy website (7%) were reported as the preferred forms of communication (Figure 5).

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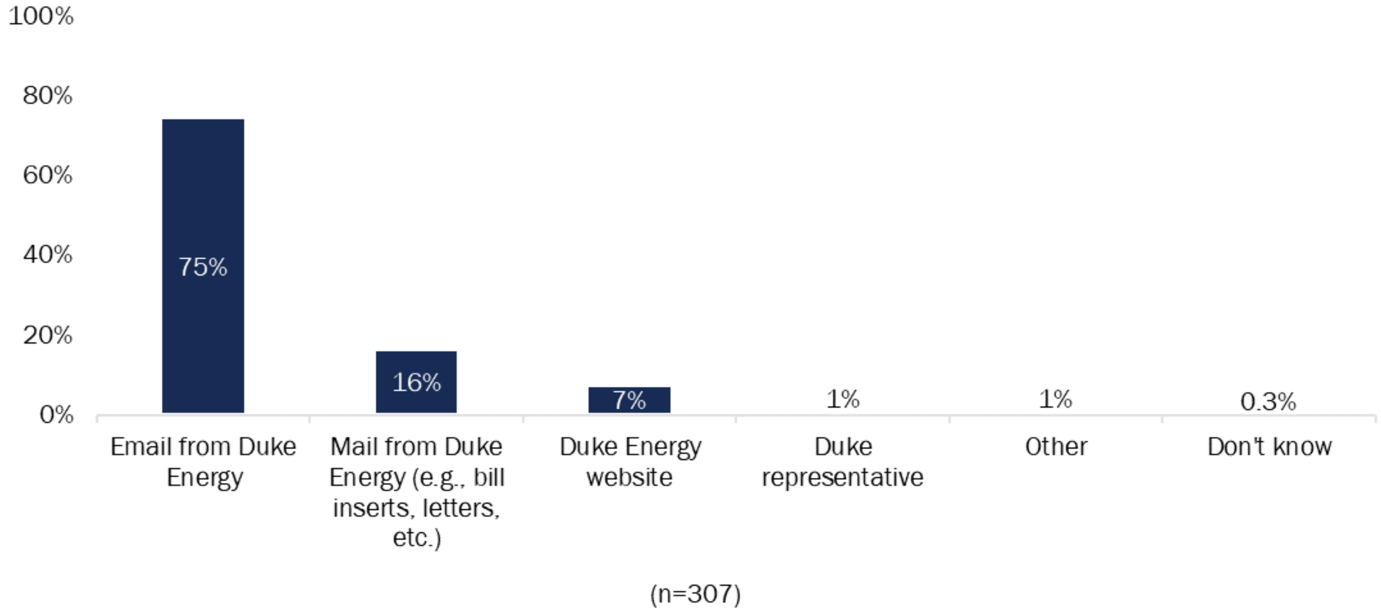
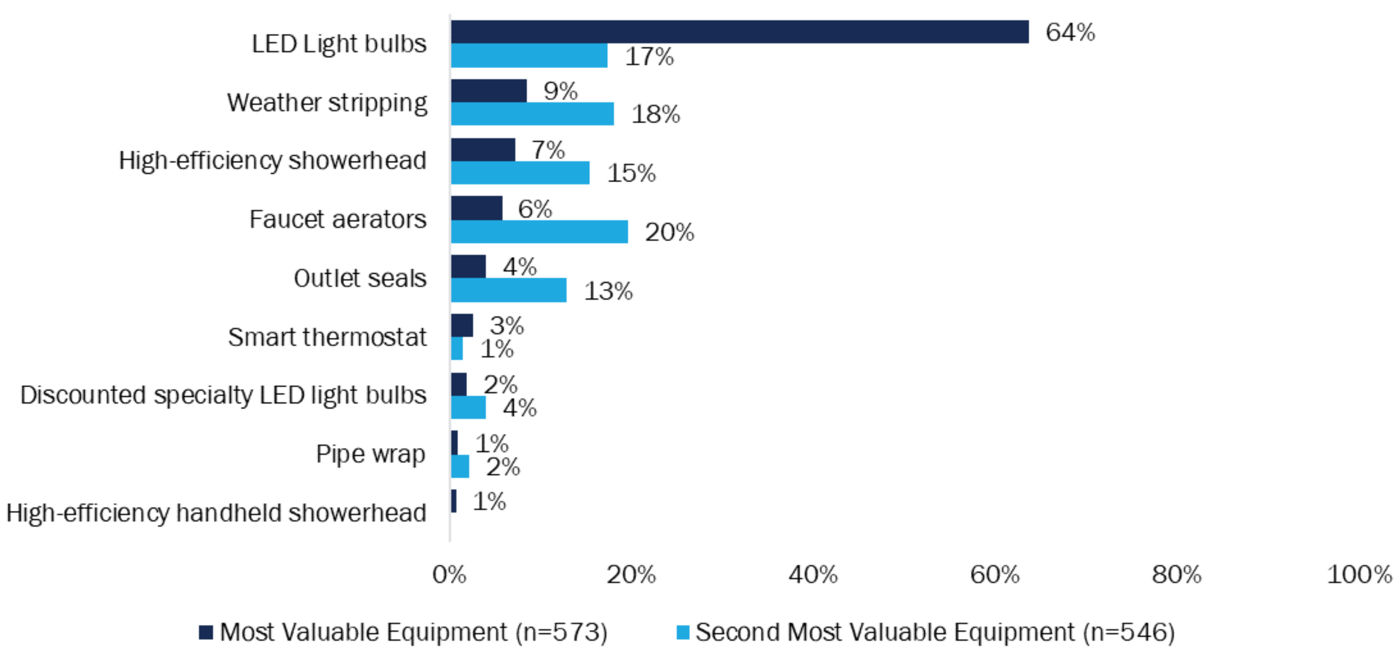
Figure 5. DEP Preferred Forms of Communication



6.3 VALUE OF PROGRAM OFFERINGS

Respondents were asked to identify the most valuable measures among the energy-efficient equipment offered by the REA Program. Sixty-four percent of DEC respondents indicated the free LED light bulbs were the most valuable measure, followed by weather stripping (9%). Discounted energy-efficient measures and the free pipe wrap were found to be valuable by less than 5% of the 573 DEC respondents.

Figure 6. DEC Most Valuable Measures



Findings are similar among DEP respondents as 54% noted that free LED light bulbs were the most valuable measure among the energy-efficient equipment offered by the program. Discounted measures and pipe wrap were considered the least valuable among the equipment offered by the REA Program according to DEP respondents.

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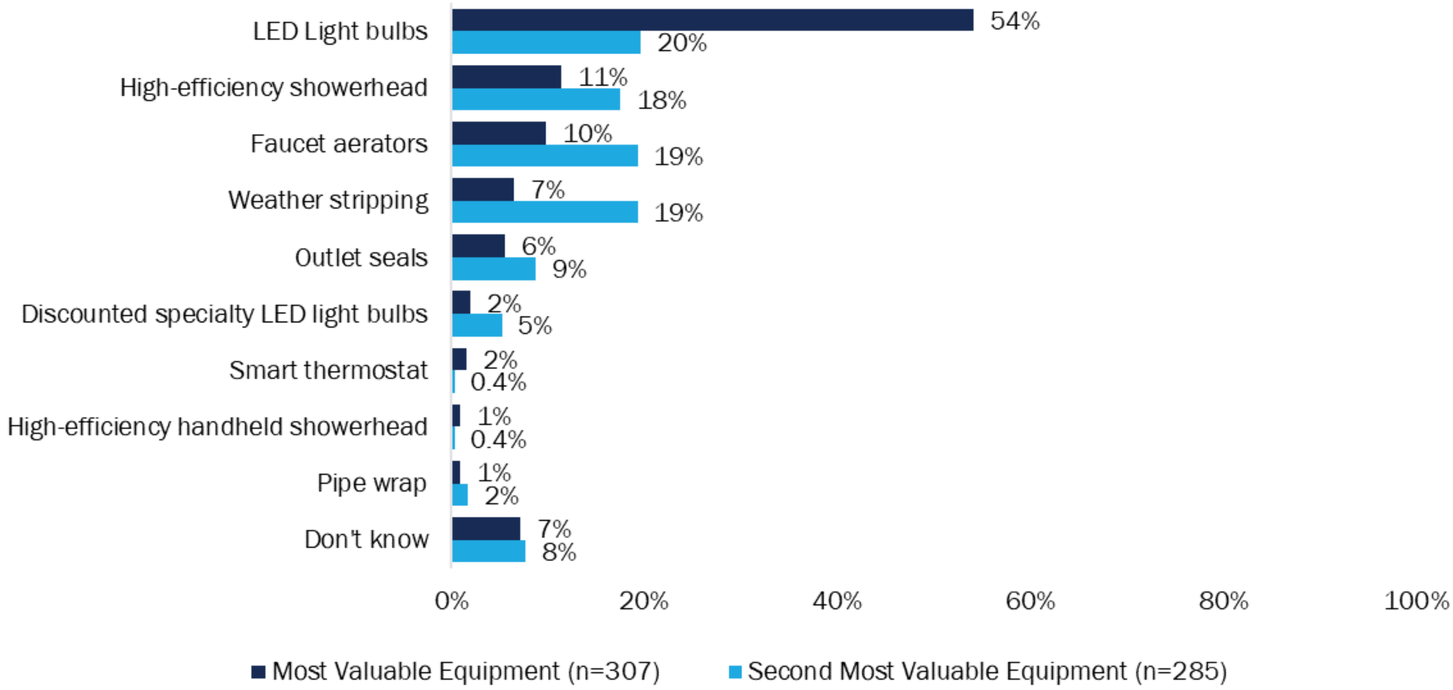
Figure 7. DEP Most Valuable Measures



Respondents were asked what other energy-efficient equipment, not currently offered by the REA Program, they would like to see offered by the program. Notably, 50% of DEC respondents and 44% of DEP respondents indicated the program offered all the equipment they wanted (Figure 8 and Figure 9). The remaining DEC and DEP respondents indicated that envelope/shell measures, additional free or discounted LEDs, air leakage tests, and duct work would have been beneficial. While nearly half of program participants believe the program is fully meeting their needs, there may be additional energy-savings opportunities if the program were to offer insulation improvements, air and duct sealing activities, and free or discounted LEDs.

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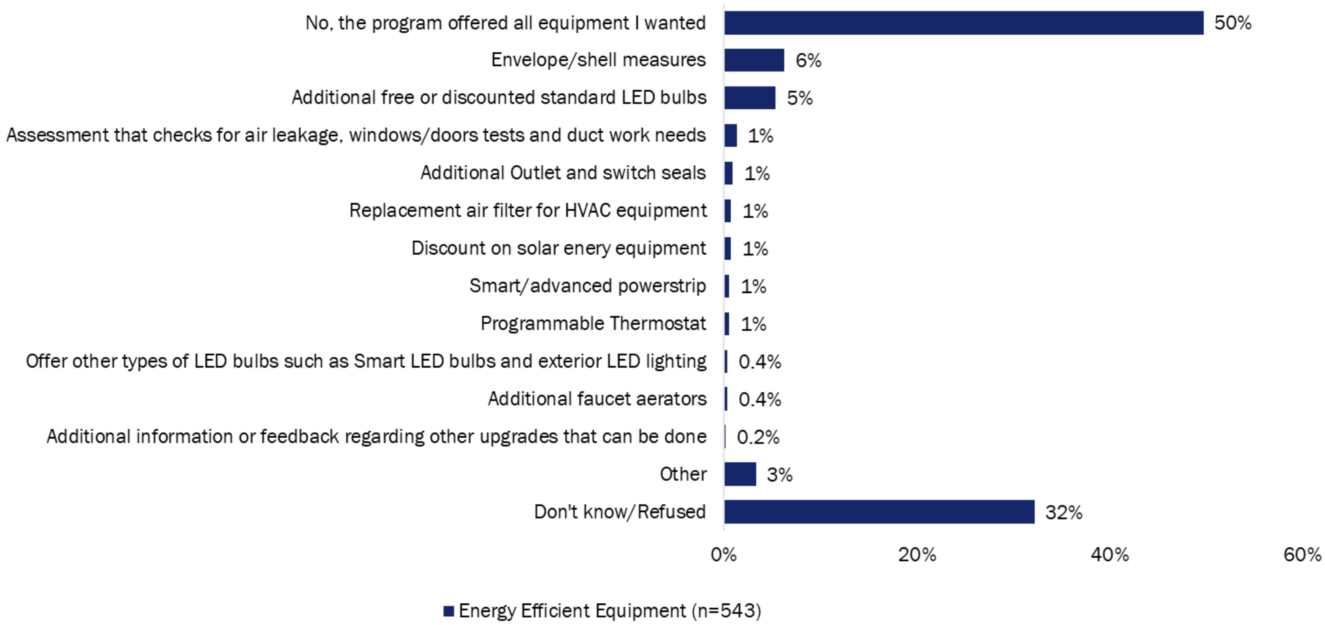
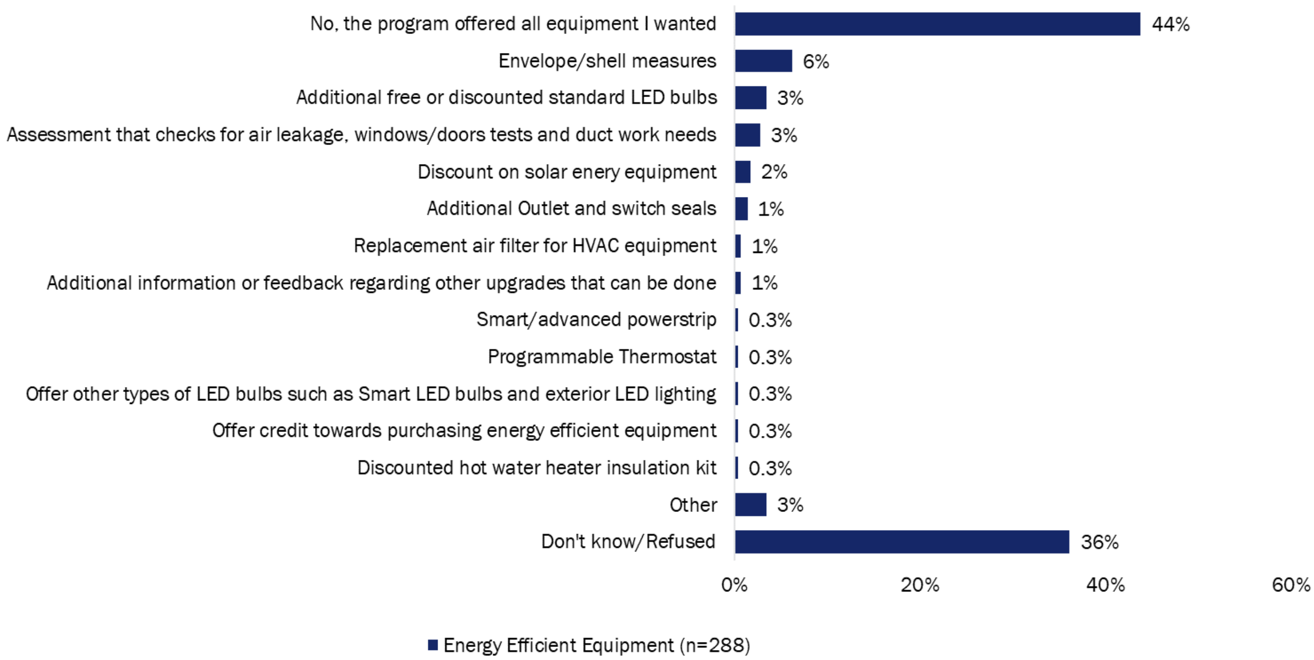
Figure 8. DEC Other Energy Efficient Equipment Needs



Note: Multiple Response
Includes valid responses only

Figure 9. DEP Other Energy Efficient Equipment Needs



Note: Multiple Response
Includes valid responses only

6.4 PROGRAM ASSESSMENT RECOMMENDATIONS

Survey results suggest that the REA Program recommendations provided to DEC and DEP participants following the assessment were both useful and actionable as most respondents reported acting on them. Actions that did not incur additional cost, such as switching lights off when not in use or washing clothes with cold water were completed by the

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majority of DEC and DEP respondents. However, some respondents reported following through on some more in-depth recommendations such as installing upgraded equipment or upgrading envelope/shell measures (Table 28 and Table 29).

As shown in Table 28, the top three recommendations received and completed by DEC respondents include performing furnace filter maintenance (81%), changing the furnace fan setting (77%),[12] and switching off lights (when not in use) (77%). Some DEC participants also installed measures not offered by the REA Program on their own. Measures include insulation and duct sealing (39%), HVAC equipment (25%), and heat pump water heaters (3%).

Table 28. DEC Program Recommendations Completed

Program Recommendations	Recommendations Received and Completed
Perform Furnace Filter Maintenance (n=226)	81%
Change Furnace Fan Setting to Auto (n=13)	77%
Switching Off the Lights (n=86)	77%
Perform Preventative Maintenance for HVAC unit(s) (n=448)	67%
Do Cold Water Washes (n=198)	67%
Insulate/Seal/Repair doors (n=29)	55%
Install Carbon Monoxide Detector (n=129)	55%
Install Energy-Efficient Lighting (n=173)	54%
Adjust Programmable Thermostat Settings (n=101)	53%
Use Window Coverings in the Summer (n=125)	53%
Close Crawl Space Vents During Winter (n=44)	52%
Unplug Electrical Devices (n=219)	43%
Seal Off and Insulate the Whole House Fan (n=29)	41%
Reduce Water Heater Temperature (n=5)	40%
Install Insulation and Duct Sealing (n=41)	39%
Install Air Sealing and Insulation in Attic (n=165)	39%
Install a Pool Timer (n=8)	38%
Install Air Sealing (n=96)	33%
Replace Existing HVAC System (n=55)	25%
Unplug Extra Freezer/Refrigerator (n=141)	21%
Install Variable Speed Pool Pump (n=17)	18%
Install Wall Insulation (n=18)	11%
Install Heat Pump Water Heater (n=34)	3%

Table 29 shows that among the recommended actions for DEP participants, all three respondents who received recommendations to reduce water heater temperature completed the recommendation. Other recommendations acted on by DEP respondents include switching lights off (79%), performing furnace filter maintenance (77%), and insulating, sealing, or repairing doors (74%). Some DEP participants also reported installing heat pump water heaters, replacing HVAC equipment, and installing insulation.

[12] Note: Low sample size for this response option

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Table 29. DEP Program Recommendations Completed

Recommendation	Recommendations Received and Completed
Reduce Water Heater Temperature (n=3)	100%
Switching Off the Lights (n=82)	79%
Perform Furnace Filter Maintenance (n=159)	77%
Insulate/Seal/Repair doors (n=23)	74%
Perform Preventative Maintenance for HVAC unit(s) (n=244)	68%
Do Cold Water Washes (n=111)	67%
Install Energy-Efficient Lighting (n=143)	59%
Install Insulation and Duct Sealing (n=24)	58%
Install Carbon Monoxide Detector (n=34)	53%
Change Furnace Fan Setting to Auto (n=17)	53%
Close Crawl Space Vents During Winter (n=53)	53%
Install a Pool Timer (n=4)	50%
Adjust Programmable Thermostat Settings (n=60)	48%
Use Window Coverings in the Summer (n=62)	45%
Unplug Electrical Devices (n=137)	42%
Install Heat Pump Water Heater (n=5)	40%
Install Air Sealing and Insulation in Attic (n=47)	38%
Install Air Sealing (n=43)	37%
Replace Existing HVAC System (n=37)	22%
Install Wall Insulation (n=5)	20%
Seal Off and Insulate the Whole House Fan (n=6)	17%
Install Variable Speed Pool Pump (n=8)	13%
Unplug Extra Freezer/Refrigerator (n=45)	7%

Respondents were asked whether they had implemented any behavior changes that resulted in saving energy since participating in the program. Figure 10 shows that 63% of DEC respondents turn off lights more frequently since participating in the program. Other actions that DEC respondents have been doing more frequently include opening curtains or shades during cooler days for natural heating (54%), cleaning lint screen in clothes dryer (54%), and closing curtains or shades at night during cooler months (54%). Overall, about one-third of DEC participants reported they have not changed their behavior with respect to energy saving activities.

Figure 11 shows that 57% of DEP respondents have been checking the dryer vent more frequently since participating in the program. DEP participants also reported that they are turning lights off when rooms are not in use (57%) and closing curtains and shades at night to prevent drafts during cooler months (52%) more frequently since participating in the program.

These findings suggest that, in addition to providing useful and actionable energy-saving recommendations, the REA Program has also been influential in getting participants to conduct certain energy-saving actions more frequently without any other incentive apart from saving energy.

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Figure 10. DEC Change in Behavior Toward Saving Energy

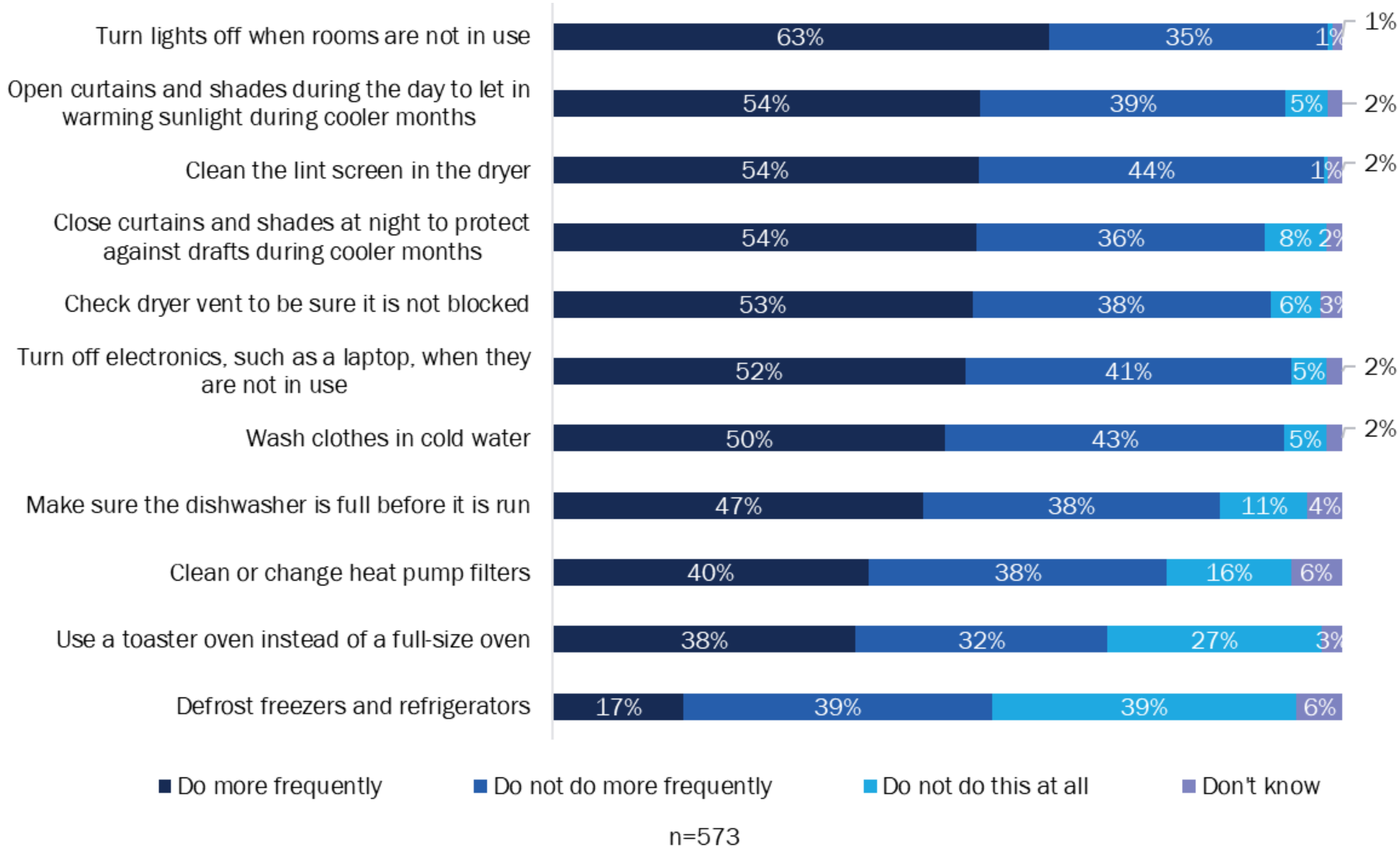
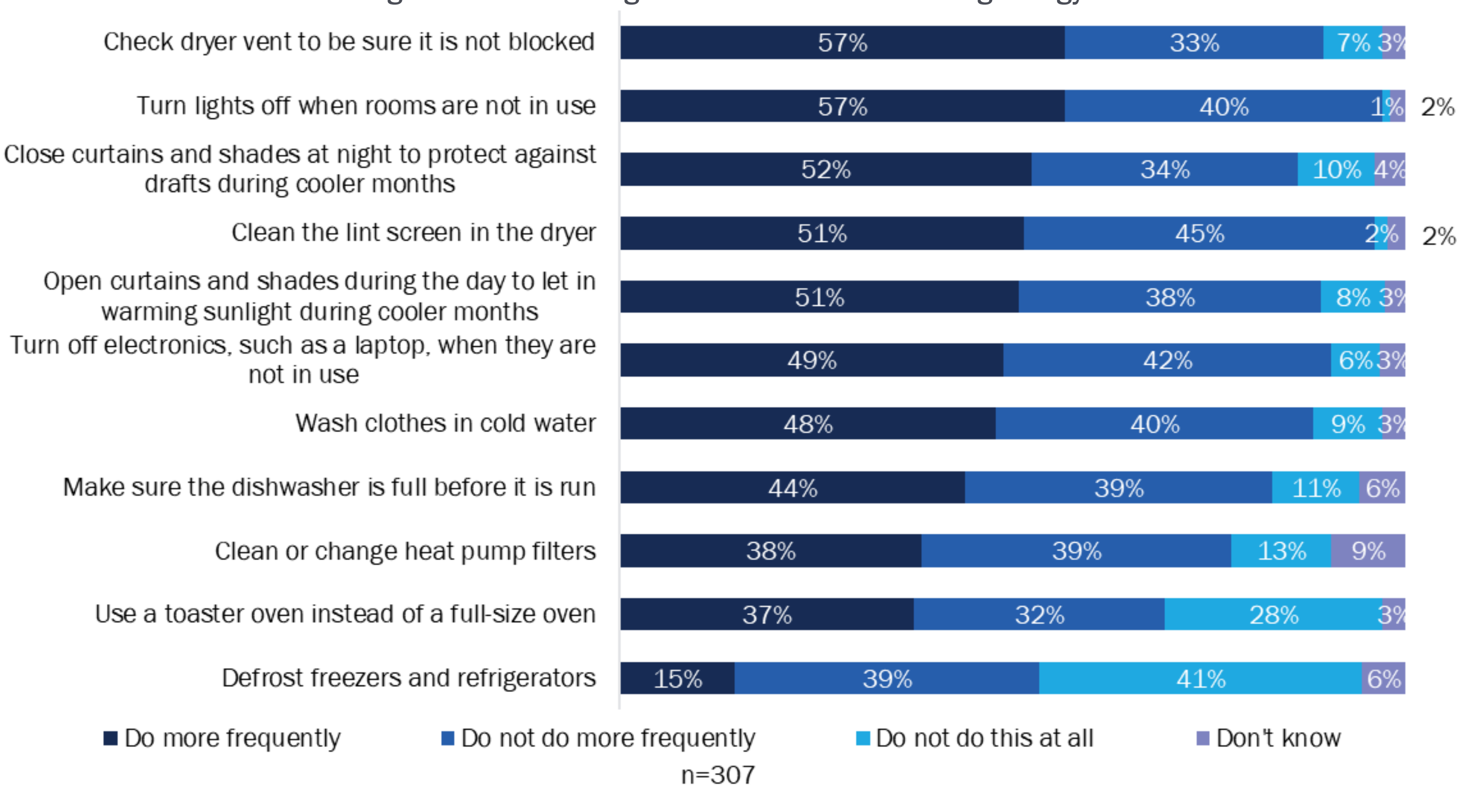


Figure 11. DEP Change in Behavior Toward Saving Energy



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6.5 CHANNELING TO OTHER DUKE PROGRAMS

In addition to receiving energy-saving measures and recommendations, some respondents also reported learning about other energy-saving programs offered by Duke Energy through the REA Program. Figure 12 and Figure 13 show that majority of DEC (78%) and DEP (76%) respondents recalled learning about the My Home Energy Report through the REA Program. Half of DEC (49%) and two-thirds of DEP (62%) respondents noted learning about home improvement rebate programs such as Duke Energy's Smart $aver Program, while about one-third of DEC (37%) and DEP (33%) respondents reported learning about air conditioner cycling programs like Power Manager.

Figure 12. DEC Other Duke Energy Programs

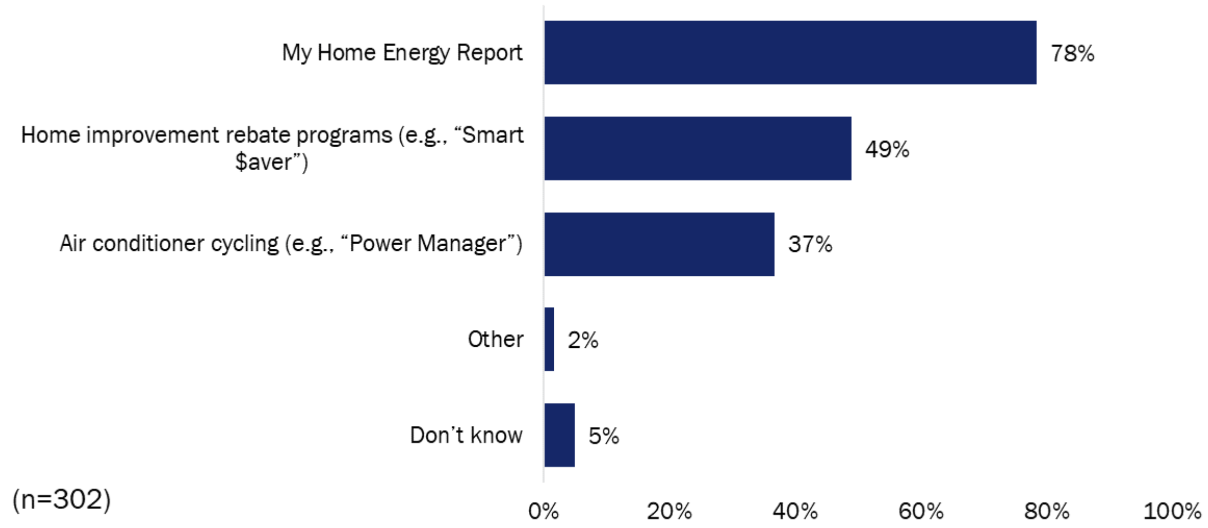
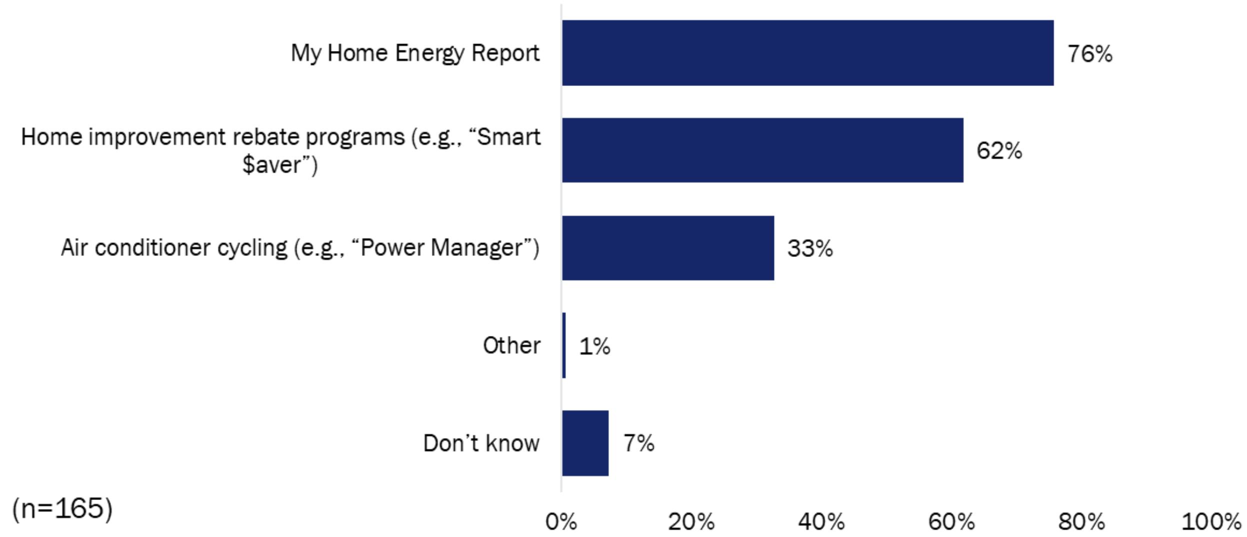


Figure 13. DEP Other Duke Energy Programs



6.6 DRIVERS OF AND BARRIERS TO PARTICIPATION

The top three drivers of program participation among DEC and DEP respondents alike are saving money on their energy bills, saving energy, and receiving free energy-efficient equipment or incentives, as shown in Table 30. Energy-efficient equipment that incurs cost, however discounted, still motivated 19% of DEC and 14% of DEP respondents to

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participate, but not as much as the free measures, which were identified as a driver of participation by 68% of DEC respondents and 67% of DEP respondents. These results suggest that free measures are more effective in encouraging program participation than discounted measures. The results also suggest that the cost and energy savings offered by the REA Program are very strong drivers of participation.

Table 30. DEC and DEP Drivers of Program Participation

Drivers of Participation in REA	DEC (n=573)	DEP (n=307)
Saving money on utility or energy bill	98%	96%
Saving energy	95%	94%
Free or no-cost energy efficient equipment	68%	67%
Needed to replace energy using equipment in household	37%	41%
The discounted energy saving equipment offered by the program	19%	14%
Energy assessment/home's energy use	4%	5%

As shown in Table 32, respondents indicated that the leading barriers to the purchase of discounted equipment are the existence of similar equipment in participants' homes and equipment preference. More than two-thirds of DEC (73%) and DEP (71%) participants who did not purchase any discounted equipment were aware that the REA Program offered discounted specialty lighting, handheld showerheads, and smart thermostats.[13] This suggests that awareness of discounted program measures is only a potential barrier for about one-third of participants.

Table 31. Reasons for Not Purchasing Discounted Equipment

Reason for Not Purchasing Discounted Equipment	DEC (n=304)	DEP (n=156)
We already have the discounted products being offered	56%	51%
We did not like the discounted products being offered	12%	13%
It was not offered to us	6%	4%
Discounted item was not compatible with related equipment/fixture	3%	4%
Cost/did not want to spend money	3%	4%
No need for any of the discounted measures	4%	3%
Other	3%	2%
Don't know	14%	19%

6.7 PARTICIPANT SATISFACTION

Overall program satisfaction was high among DEC and DEP respondents as 80% of DEC and 77% of DEP respondents reported being satisfied with the program, shown in Figure 14 and Figure 15, respectively. The mean satisfaction ratings were 8.6 and 8.4 from DEC and DEP respondents, respectively. Survey results suggest these high satisfaction scores provided by DEC and DEP respondents may be attributed to proper program implementation through the energy-efficient measures offered and the energy-saving recommendations provided by the program.

[13] Note that the number of respondents for this question are 418 for DEC and 219 for DEP. The respondents were first asked if they were aware that the Program offered discounted measures. Those who said they were aware were then asked a follow up question, which asked why they did not purchase discounted measures. Results to this follow up question are summarized in Table 31.

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Figure 14. DEC Overall Program Satisfaction

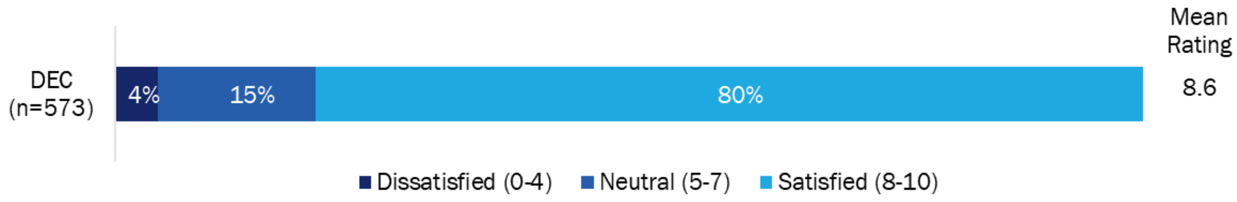
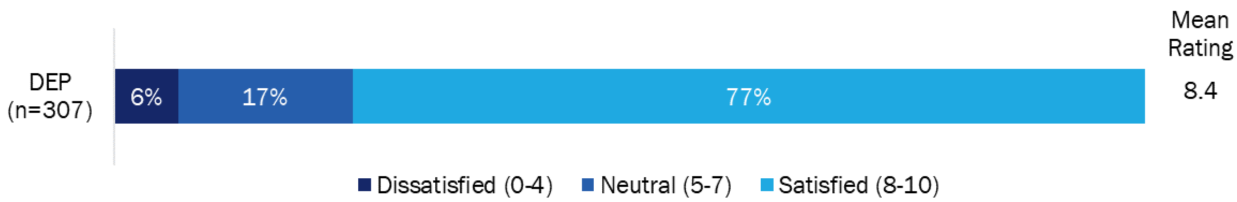


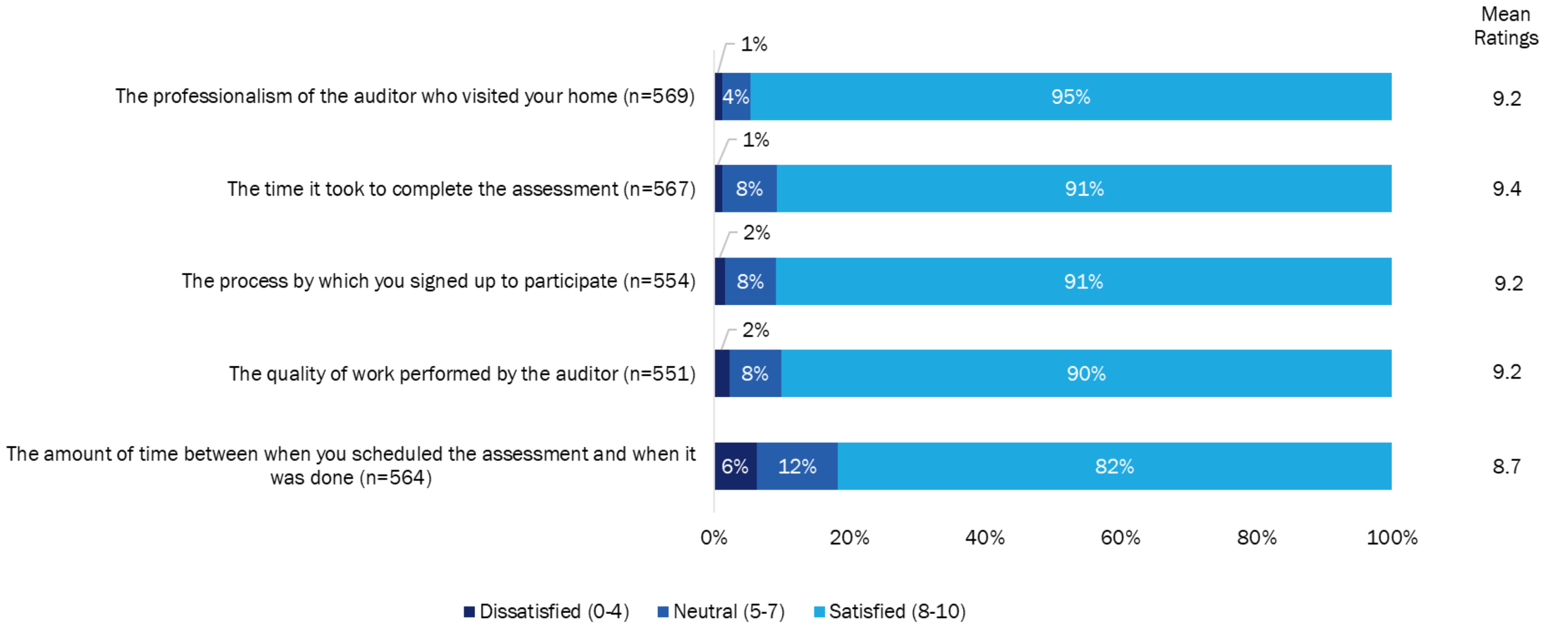
Figure 15. DEP Overall Program Satisfaction



Satisfaction scores provided by both DEC and DEP respondents for the various components of the program suggest that participants are satisfied with how it was implemented. A limited number of respondents expressed dissatisfaction with any program components, which suggests that the program was implemented properly and smoothly during the program period from September 1, 2020, to August 31, 2021. Part of this program period took place during the COVID-19 pandemic, at which time various jurisdictions and energy efficiency programs experienced disruptions in implementation, staffing shortages, and supply chain issues.

DEC respondents were most satisfied with the professionalism of the auditor of all program components, with 95% of respondents reported being extremely satisfied. Most (91%) were also satisfied with the time it took to complete the assessment, the participation process (91%), and the work quality of the auditor (90%) (Figure 16). These high satisfactions scores suggest that DEC and DEP respondents encountered little to no significant challenges in participating in the program and were able to participate with ease.

Figure 16. DEC Program Component Satisfaction



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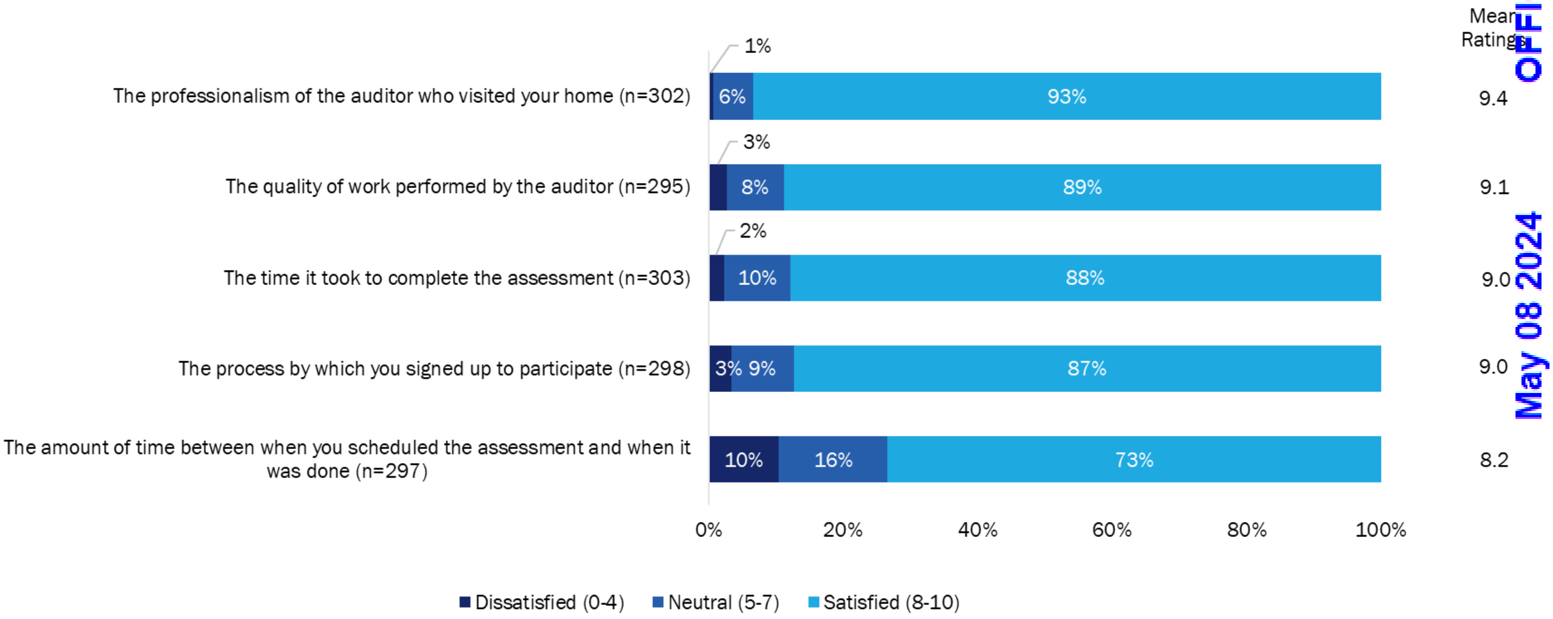
The majority of DEP respondents were also extremely satisfied with the professionalism of the auditor (93%), followed by the auditor's work quality (89%), and the time it took to complete the assessment (88%) (Figure 17).

Figure 17. DEP Program Component Satisfaction



In addition to high satisfaction scores for the various program components, results suggest that participants were satisfied with the energy-efficient equipment and energy-saving recommendations provided by the program.

All respondents for both jurisdictions reported being extremely satisfied with the energy-saving recommendations they received from the program (Figure 18 and Figure 19). The majority of DEC (81%) and DEP (79%) respondents indicated being satisfied with the Assessment Report they received through the program. Most respondents for both jurisdictions also reported being extremely satisfied with the discounted handheld showerhead, smart thermostat, and specialty LEDs. Both DEC (77%) and DEP (76%) respondents also reported satisfaction with starter kit measures. This is consistent with the free measures being a key driver of participation. However, there may be opportunities to assess the starter kit measures. Some respondents who reported dissatisfaction with the free measures noted that they already had the free measures being offered in the starter kit.

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Figure 18. DEC Program Offering Satisfaction

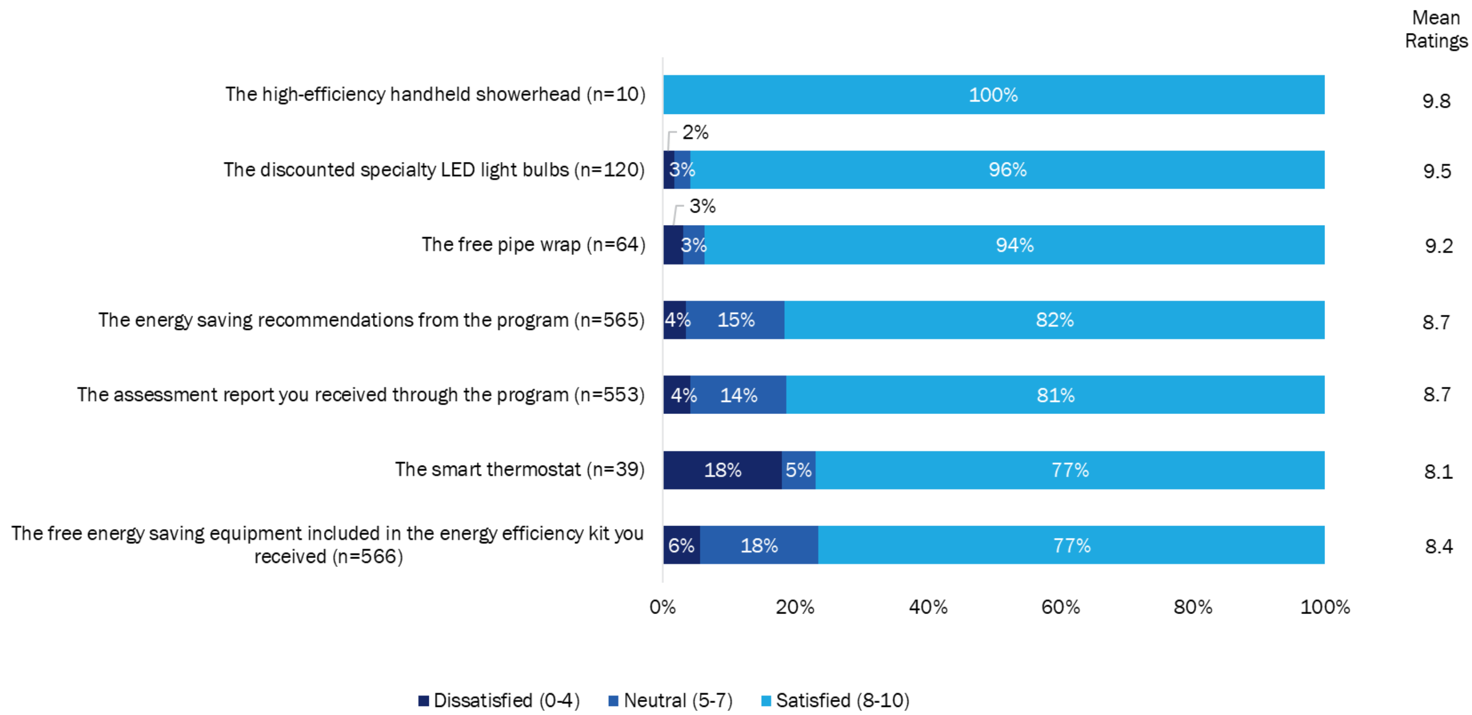
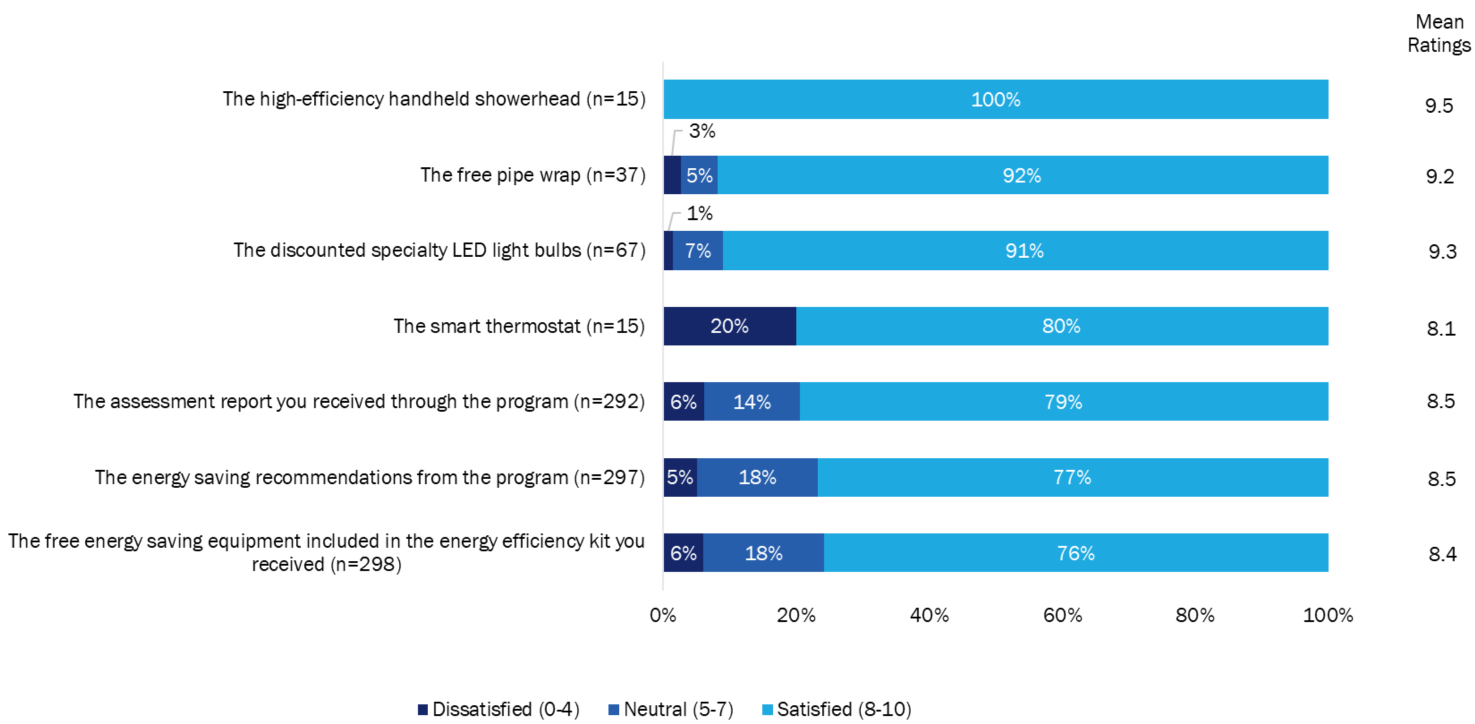


Figure 19. DEP Program Offering Satisfaction



6.1 SMART THERMOSTAT DEVICE ENGAGEMENT

In addition to the process analysis, Duke staff expressed interest in smart thermostats and how participants engage with smart thermostats. As such, we included a few questions regarding smart thermostats in the participant survey to

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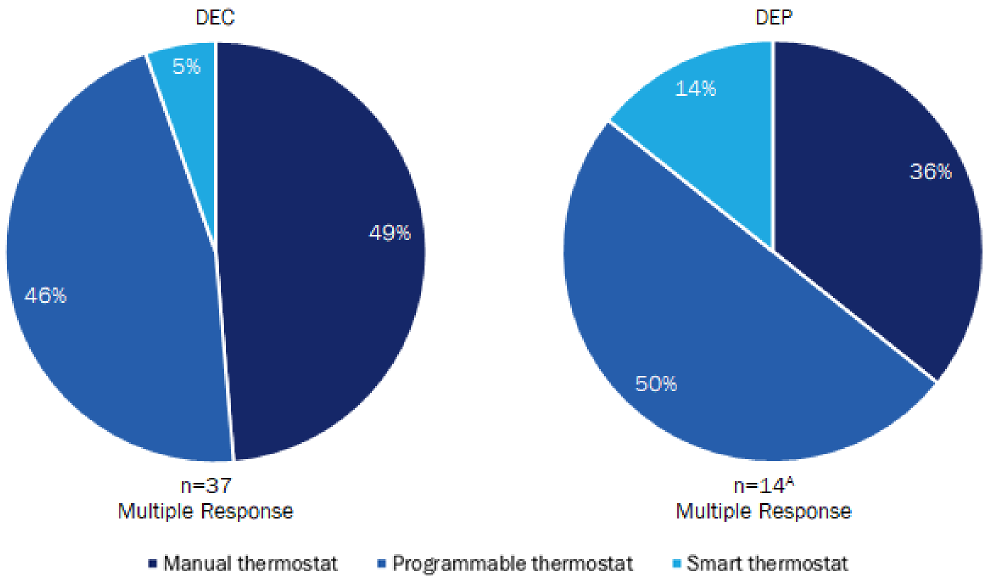
determine the types of thermostats DEC and DEP REA participants may be using prior to installing smart thermostats and which control features they are using.

DEC and DEP participants who purchased discounted smart thermostats through the REA Program replaced either a manual, programmable, or smart thermostat. Nearly half of DEC participants who purchased a smart thermostat replaced a manual thermostat, while half of DEP participants who purchased a discounted smart thermostat replaced a programmable thermostat (Figure 20).

Figure 20. DEC and DEP Types of Thermostats Replaced by Discounted Smart Thermostat



A Low sample size

When asked about how they controlled the temperature settings on their previous thermostat(s) during summer months when cooling their homes, the majority of DEC (70%) customers reported manually adjusting their old thermostats.

To control temperature settings in their new smart thermostats, DEC respondents took advantage of other features such as a programmed schedule (43%) or self-optimization (22%), while 22% still manually adjusted their thermostat or used a single temperature setting (14%) as shown in Figure 21.

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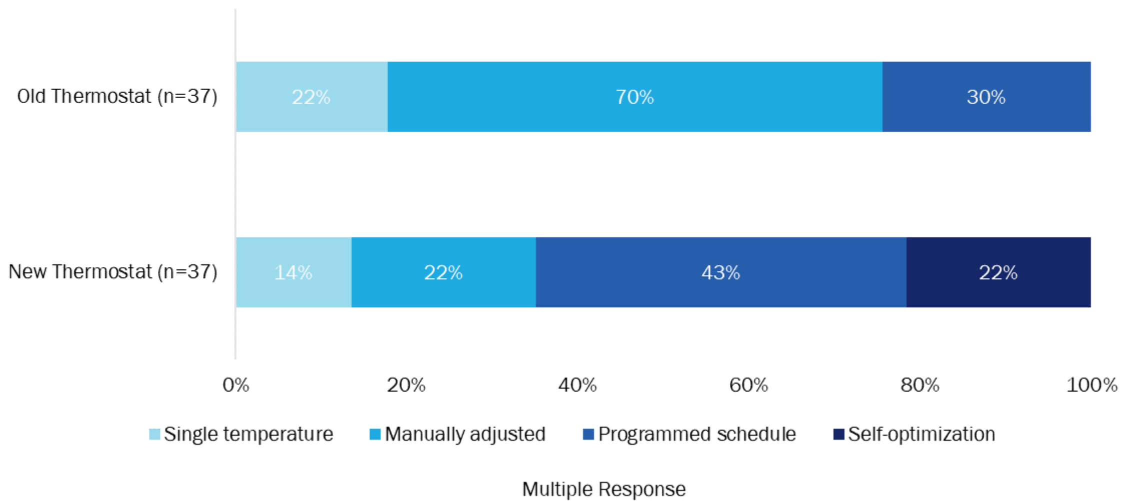
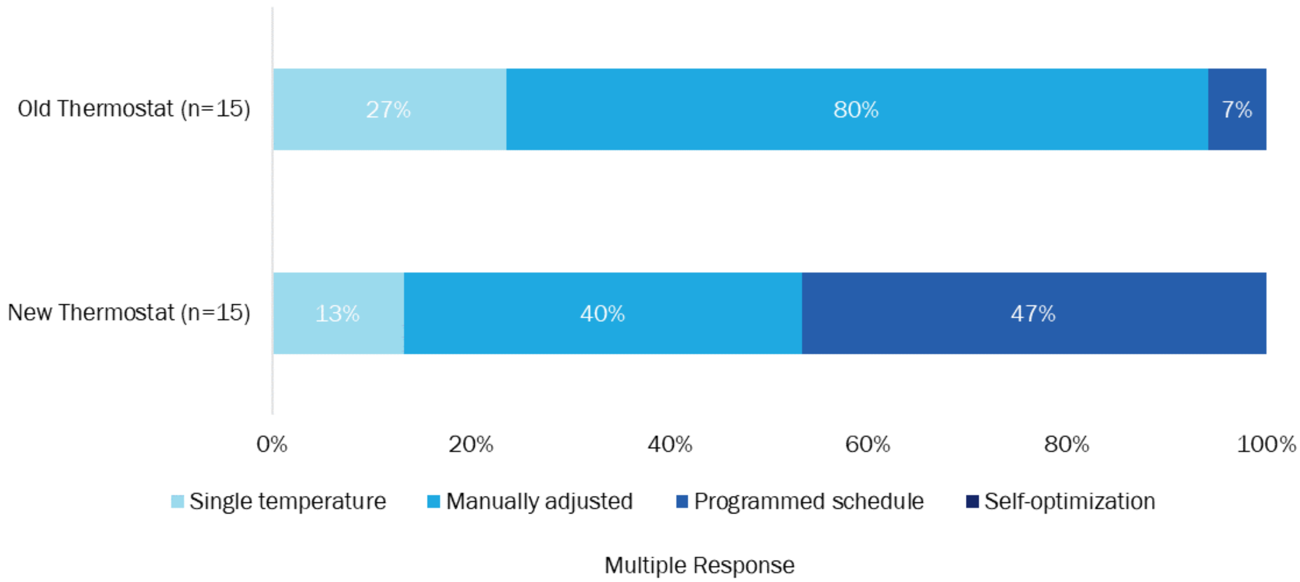
Figure 21. DEC Smart Thermostat Control



Most DEP respondents (80%) noted that they manually controlled their old thermostats to control temperature settings in the summer months. However, after they installed the smart thermostat they purchased through the Program, those who still manually adjusted their smart thermostat decreased to 40% while those who used a programmed schedule increased to 47% (Figure 22).

Figure 22. DEP Smart Thermostat Control



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7. KEY FINDINGS AND RECOMMENDATIONS

7.1 KEY FINDINGS

Over the evaluation period, September 2020 to August 2021, the REA Program served 10,171 unique households in the DEC jurisdiction and 5,996 households in the DEP jurisdiction. The program saved DEC and DEP participants, on average, 559 kWh and 743 kWh per household per year, respectively. These estimates include savings from equipment installed by auditors, as well as savings from any additional behavioral changes and participant SO attributable to the program.

The engineering analysis included development of ISRs and a review of deemed savings values. As discussed in Section 4.2.2, ISRs are low for most starter kit measures. Responses from the survey indicated that auditors were not installing all measures, starter kit equipment did not fit, participants already had efficient measures installed, and/or participants wanted to reduce the time auditors spent in their homes due to COVID-19 concerns. The ISRs are much higher for discounted measures purchased through the program, which is expected as customers are more likely to install measures for which they have paid and reflects program guidelines that auditors install all discounted equipment. The lower ISRs for domestic hot water measures stem from relatively low verification rates, and to a limited extent, lower persistence rates.

Our engineering analysis provided additional insight into the relative contribution of each measure type to program savings. We found that lighting is responsible for the largest proportion of savings (28% for DEC and 28% for DEP) followed by low-flow showerheads (18% for DEC and 21% for DEP).

We also estimated NTGRs for all measures provided through the REA Program for both DEC and DEP. As noted in Section 5, the NTGR represents the portion of the gross energy savings associated with program-supported measures that would not have been realized in the absence of the program. Our analysis estimated NTGRs greater than 100% for all measures included in the starter kit except for LEDs.

Results from the process analysis suggest that DEC and DEP participants were satisfied with the REA Program. The various program components such as the professionalism of the auditor, the time it took to complete the assessment, and the participation process contributed to high satisfaction scores. Among the program offerings, the discounted handheld showerheads, discounted specialty LEDs, and the free pipe wrap were among the equipment that contributed to higher satisfaction scores. The process analysis results also suggest that the recommendations provided by the program are useful and actionable as many participants completed at least one recommendation from the program, contributing to high spillover rates. Energy bill savings and saving energy are two main drivers to participation, while barriers to participation include already having the measures offered by the program or simply dislike for the measures being offered.

7.2 EVALUATION RECOMMENDATIONS

Based on our evaluation activities, we present the following recommendations for consideration by Duke Energy.

Consider having program auditors provide only those starter kit measures that are installed during the inspection. Many of the starter kit measures displayed low ISRs and homeowners reported that they did not need many of the measures that were left behind with the starter kit. This issue was likely exacerbated by the COVID-19 pandemic as homeowners were interested in shorter audits. Moving forward, it would benefit the program to have auditors provide only the starter kit measures that are applicable in each participant home, as opposed to leaving measures behind for

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homeowner installation. This change would ensure that (1) only applicable measures are provided to each participant and (2) those measures are installed.

Continue to promote other Duke Energy programs through the REA participation process. Respondents reported learning about other Duke Energy programs, such as the My Home Energy Report and Smart Saver offerings, through the REA Program. The Smart Saver program, in particular, offers deep energy saving measures such as HVAC equipment, water heating equipment, air and duct sealing, and attic insulation, that are not currently offered through the REA Program. Building shell insulation (e.g., wall, ceiling, and floor insulation) was the most frequently cited measure when participants were asked which energy saving measures they would like to see offered by the program moving forward. Alternatively, the program could consider offering these measures at a discount directly through the REA Program. This would, however, require a follow-up visit from a program representative, which is not currently part of the program design and would increase the cost of program delivery.

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8. EM&V FACT SHEET

DUKE ENERGY CAROLINAS / DUKE ENERGY PROGRESS RESIDENTIAL ENERGY ASSESSMENT PROGRAM

COMPLETED EM&V FACT SHEET

PROGRAM DESCRIPTION

The Residential Energy Assessment Program offers participants a home energy assessment, a starter kit of free low-cost energy-efficient measures, and a small selection of additional free measures. An auditor report of recommended upgrades and a booklet of suggested behavioral changes are given to the customer at the end of the assessment. Customers also have the option to purchase certain energy efficiency equipment at a discount.

Date:	November 27, 2023
Region(s):	Duke Energy Carolinas and Progress
Evaluation Period:	September 1, 2020 - August 31, 2021
Annual kWh Savings (ex post net):	DEC: 5,685,589 kWh DEP: 4,432,738 kWh
Coincident kW Impact (ex post net):	DEC: 1,003.84 kW (Summer), 782.10 kW (Winter) DEP: 782.64 kW (Summer) 609.76 kW (Winter)
Measure Life:	Not Evaluated
Net-to-Gross Ratio:	DEC: 115% DEP: 122%
Process Evaluation:	DEC: Yes DEP: Yes
Previous Evaluation(s):	Duke Energy Carolinas Residential Energy Assessment Program Evaluation, October 12, 2018 Duke Energy Progress Residential Energy Assessment Program Evaluation, October 12, 2018

EVALUATION METHODOLOGY

The evaluation team verified measure-level deemed savings estimates using an engineering analysis of savings assumptions and calculations. The evaluation team also leveraged a participant survey to verify installation and in-service rates for each measure and to estimate a net-to-gross ratio. The evaluation team conducted a consumption analysis to estimate energy savings and used a combination of a consumption analysis and engineering analysis results to estimate coincident demand savings.

EVALUATION FINDINGS

- For the consumption analysis, a Linear Fixed Effects Regression (LFER) model with a matched comparison group of future participants was used, which established a statistically significant relationship between participation in the program and energy consumption.
- The engineering analysis showed that the measures with the greatest contribution toward savings were lighting followed by low-flow showerheads.

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9. DSMORE TABLE

The evaluation team relied on the consumption analysis and engineering analysis to arrive at DSMore savings values for the energy efficiency starter kit and additional measures offered through the program.

The evaluation team subtracted out the savings from the average number of additional measures from the program savings estimated using a consumption analysis. The savings for all rebated measures were based on the ex post engineering-based savings values.

The Excel spreadsheet containing measure-level inputs for Duke Energy Analytics is provided below. Per-measure savings values in the spreadsheet are based on the gross and net impact analyses reported in the earlier sections of this report. The evaluation scope did not include updates to measure life assumptions.

REA_DEC-DEP2022_
DSMore Table.xlsx

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APPENDIX A. DETAILED CONSUMPTION ANALYSIS METHODOLOGY

The evaluation team conducted a consumption analysis using a Linear Fixed Effect Regression (LFER) model, with the goal of determining the overall ex post net program savings. The model allows all household factors that do not vary over time to be absorbed by (and therefore controlled for) the individual constant terms in the equation. In other words, this method uses account-specific intercepts.

As part of the consumption analysis of Residential Energy Assessment (REA) Program participants, the evaluation team followed a standard series of steps for data collection, data cleaning, model specification, and analysis.

PARTICIPANT DATA PREPARATION

The participant dataset contained a range of data fields with participation attributes including participant identifiers, participation dates, measure detail, and participant housing characteristics, among others. The participant data set included customers who participated in the program between September 1, 2020, and August 31, 2022 (including both the treatment group and the comparison group of future participants). We checked for participants without participation dates as well as those with participation dates outside of the program period under evaluation and carefully explored available participation dates to identify those that best reflect the program treatment start. This step is particularly important, as it allows us to accurately categorize billing periods into pre- or post-intervention periods. After analysis of the available date fields and discussions with Duke Energy evaluation and program staff, we settled on the date field Customer Participation Start Date. Finally, we identified and removed two participating accounts that did not merge with the consumption data. The remaining participants were included in the cleaning of the consumption data.

COMPARISON GROUP SELECTION

A key challenge for estimating energy savings via a consumption analysis is the identification of an appropriate comparison group to represent a baseline for how much energy the customers would have consumed in the absence of the program. We consider two main factors in the design of a comparison group. A comparison group must (1) have similar energy usage patterns (compared to participants) before participation (i.e., pre-participation period) and (2) effectively address self-selection bias (the correlation between the propensity to participate in a program and energy use). In an ideal experimental design, a randomized control group would be used, and it would be equivalent to the treatment group in all aspects, save for the treatment being evaluated (in this case, participation in the REA Program). When a randomized control trial is not feasible, we use a matched comparison group using usage and other characteristics. A perfect match is impossible when studying the effects of energy efficiency programs, since we cannot know if any group of non-participants is equivalent to the participant group, especially on the dimension of what the participants would have done absent the program. We generally cannot even know whether a “matched” customer might be in the market for relevant equipment. Achieving similarity on usage supports our claim that estimates from our quasi-experiment are representative on usage patterns at least, which reflects not only a household’s level of use but its energy-related responses to changes in the weather, economic, and political environment. It is more difficult to ensure the comparison group represents what the participants would have done absent the program.

Where we could establish a reasonable level of equivalency, we relied on future participants as a comparison group for this analysis. The use of future participants allowed us to better control for self-selection, because those customers in the comparison group also chose to participate in the same program, just later. However, leveraging future participants as a comparison group may not always be possible due to differences in participant composition over time, due to targeting, natural self-selection, and other reasons.

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To support the evaluation of this program, we first attempted to construct a comparison group comprised of future participants who participated between September 1, 2021, and August 31, 2022. Upon initial explorations we determined that future participants do not represent a strong comparison group. As a result, we deployed Mahalanobis distance matching algorithms to narrow down the population of future participants to a more comparable to treatment participants subpopulation. We performed matching with replacement, that is, one comparison group customer could be matched to multiple participating customers. We reviewed the performance of each matching method using statistical approaches (standardized bias calculated both annually and for the heating and cooling seasons),[14] and by visually inspecting the closeness of the matches between participants and the comparison group. We verified the equivalency of the participant and matched comparison groups by conducting equivalency checks based on their pre-period energy usage, weather, and other available characteristics. The sections below provide additional details for these equivalency checks.

CONSUMPTION DATA PREPARATION

Upon merging participant and consumption data, we performed the following consumption data cleaning steps:

- Duplicate records. We explored duplicate records and made adjustments to arrive at a single bill per period.
- Inadequate days. We identified and dropped bill periods with zero or negative days.
- Extremely low Average Daily Consumption. We checked for and dropped bills with very low (less than zero kWh) or missing average daily consumption.
- Extremely high Average Daily Consumption. We checked for customers with entire pre- or post-installation periods having very high (exceeding three times the standard deviation) average usage.
- Inadequate billing history before or after program participation. Many energy-saving measures in these programs are expected to generate energy savings throughout the year. To assess changes in consumption due to program measures before and after installation, we need to ensure that participants have a billing history covering, at a minimum, nine months (or the 270-day equivalent) in the pre- and post-installation periods.
- Insufficient billing history in the heating season before and after program participation. We also required participants to have a minimum of 75% of the heating season (November through March) in the pre-participation and post-participation periods.
- Insufficient billing history in the cooling season before and after program participation. Similar to the heating season, we required participants to have a minimum of 75% of the cooling season (June through August) in the pre-participation and post-participation periods.
- Removing consumption records for cross-participants. We identified and removed REA Program participants as well as comparison group customers who cross-participated in other programs administered by Duke Energy following REA Program participation. Customers were only removed if they cross-participated during the evaluation period or the post-period. The average per-participant savings estimate was multiplied by the total number of evaluated participants; however, including those that participated in other programs, to determine total program savings.

Table 32 contains a summary of the accounts dropped as part of each cleaning step for treatment and comparison groups comprised of future participants. The table presents results separately for DEC and DEP. As shown, the largest

[14] The standardized bias is the difference between the mean of average daily consumption for participants and comparison group customers divided by the standard deviation of the average daily consumption for participants. In general, a matching method with smaller standardized bias produces better overall matches, and a standardized bias of less than 0.25 implies a good match.

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drops are associated with insufficient pre-period and post-period consumption. Data cleaning efforts resulted in a similar level of drops for DEC and DEP. More specifically, upon completing data cleaning, we retained 62% of DEC and DEP treatment group participants, 52% of DEC comparison group participants, and 55% of DEP comparison group participants.

Table 32. Summary of Data Cleaning Results

Drop Reason	Treatment Accounts Remaining		Comparison Accounts Remaining	
	N	%	N	%
DEC				
Total	10,049	100%	6,375	100%
Duplicate Records	10,049	100%	6,375	100%
Inadequate Days	10,049	100%	6,375	100%
NA or Negative Usage	10,049	100%	6,375	100%
Outliers	10,049	100%	6,373	100%
Long Bills	10,049	100%	6,373	100%
Pre-period Sufficiency	8,436	84%	4,136	65%
Post-Period Sufficiency	8,074	80%	4,096	64%
75% Heating Days in Pre	7,948	79%	4,018	63%
75% Heating Days in Post	7,927	79%	3,975	62%
75% Cooling Days in Pre	7,604	76%	3,933	62%
75% Cooling Days in Post	6,313	63%	3,869	61%
Gaps and Overlaps	6,313	63%	3,869	61%
Cross Participation	6,217	62%	3,325	52%
DEP				
Total	5,904	100%	4,666	100%
Duplicate Records	5,904	100%	4,666	100%
Inadequate Days	5,904	100%	4,666	100%
NA or Negative Usage	5,904	100%	4,666	100%
Outliers	5,904	100%	4,666	100%
Long Bills	5,904	100%	4,666	100%
Pre-period Sufficiency	5,099	86%	3,170	68%
Post-Period Sufficiency	4,819	82%	3,148	67%
75% Heating Days in Pre	4,753	81%	3,089	66%
75% Heating Days in Post	4,739	80%	3,012	65%
75% Cooling Days in Pre	4,563	77%	2,959	63%
75% Cooling Days in Post	3,840	65%	2,940	63%
Gaps and Overlaps	3,840	65%	2,940	63%
Cross Participation	3,644	62%	2,544	55%

Following data cleaning, we compared the treatment customer distribution across known characteristics to ensure the customers we retained in the analysis were similar to the broader population of participants, to whom modeled results would be extrapolated. Table 33 contains the results of those comparisons. As shown in the table, participant composition post-cleaning remained largely similar across most of the observable characteristics.

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Table 33. Pre- and Post-Cleaning Treatment Participant Composition

Comparison Area	Treatment Participants Prior to Cleaning	Treatment Participants After Cleaning	Comparison Participants Prior to Cleaning	Comparison Participants After Cleaning
DEC				
Average Pre-Period Daily Consumption (kWh)	40.7	41.8	43.8	43.5
Percent of Customers with Electric Heating Source	44%	43%	52%	53%
Percent of Customers with Electric Water Heating Source	54%	53%	60%	61%
DEP				
Average Pre-Period Daily Consumption (kWh)	44.7	45.0	48.8	47.6
Percent of Customers with Electric Heating Source	59%	58%	71%	72%
Percent of Customers with Electric Water Heating Source	64%	64%	72%	74%

WEATHER DATA PREPARATION

To include weather patterns in our model, we used daily weather data from numerous weather stations across the DEC and DEP territories, utilizing the site closest to each account's geographic location. By using multiple sites, we increase the accuracy of the weather data being associated with each account. We obtained these data from the National Climatic Data Center (NCDC).

The daily data are based on hourly average temperature readings from each day. We calculated CDD and HDD for each day (in the analysis based on average daily temperatures, using the same formula used in weather forecasting).[15] We merged daily weather data into the consumption dataset so that each billing period captures the HDD and CDD for each day within that billing period (including start and end dates).[16] For analysis purposes, we then calculated average daily HDD and average daily CDD, based on the number of days within each billing period.

COMPARISON GROUP EQUIVALENCY ASSESSMENT

The appropriate use of the future participant comparison group design depends on its equivalency with the treatment group on as many dimensions as possible, including consumption during pre-participation period, weather, program implementation, and available sociodemographic data on participants. Substantial differences between the treatment and comparison groups could lead to a misrepresentation of the baseline or point of comparison. Therefore, as part of our assessment of the comparison group equivalency, we explored the following dimensions:

- Pre-period consumption
- Weather
- Household characteristics of participants

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[15] A "degree-day" is a unit of measure for recording how hot or how cold it has been over a 24-hour period. The number of degree-days applied to any particular day of the week is determined by calculating the mean temperature for the day and then comparing the mean temperature to a base value of 65°F (HDD) and 75°F (CDD). (The "mean" temperature is calculated by adding together the high for the day and the low for the day, and then dividing the result by two.) If the mean temperature for the day is five degrees higher than 75°F, then there have been five cooling degree-days. On the other hand, if the weather has been cool, and the mean temperature is, say, 55°F, then there have been 10 heating degree-days (65 minus 55). "Degree Days," National Weather Service, https://www.weather.gov/ffc/degdays.

[16] Daily weather data are merged based on the given dates of the billing period. Assigning weather this way provides a more accurate representation of the weather experienced during the billing period than does using weather for the calendar month of the bill.

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Figure 23 and Figure 24 summarize consumption trends (ADC or average daily consumption) between treatment and comparison groups following the matching process, while Figure 25 and Figure 26 compare HDD and Figure 27 and Figure 28 compare CDD between treatment and comparison groups, respectively. Weather patterns are very similar between treatment and comparison participants.

Figure 23. DEC Participant and Comparison Group Usage During their Pre-Participation Period – Post-Matching

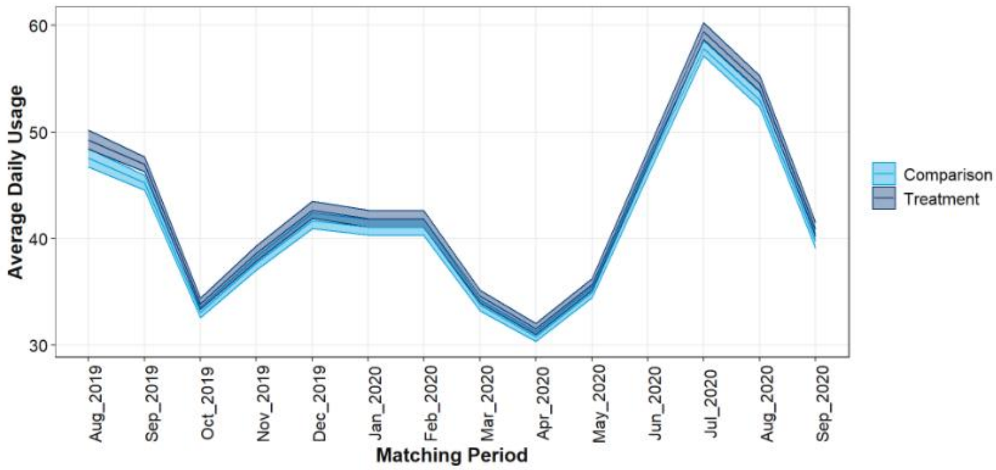

Figure 24. DEP Participant and Comparison Group Usage During their Pre-Participation Period – Post-Matching

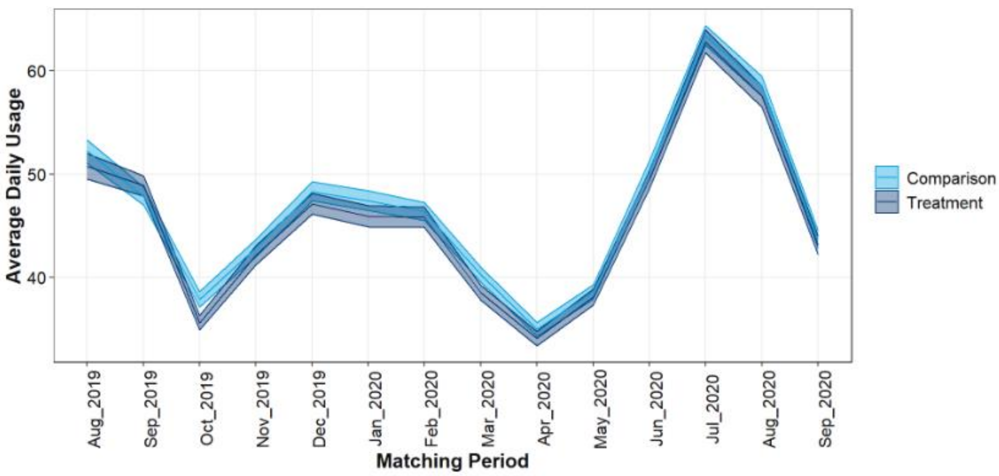

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Figure 25. DEC Average HDD Experienced by Treatment and Comparison Groups

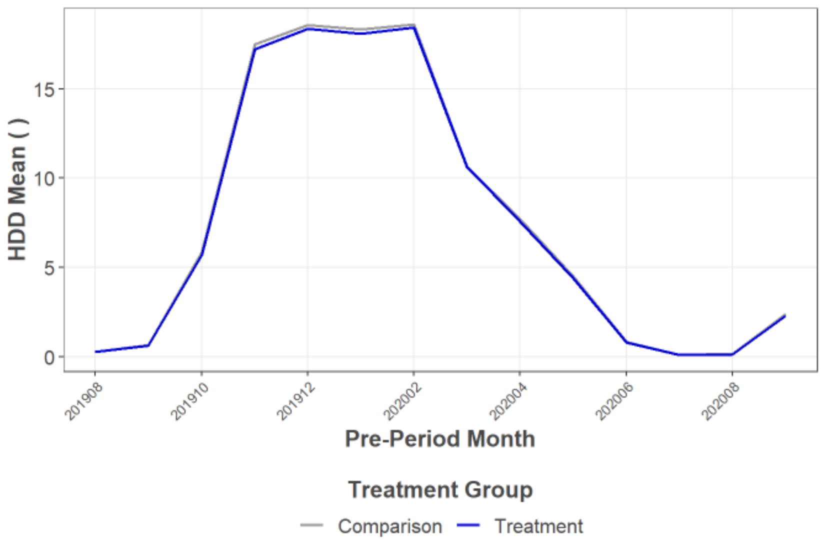

Figure 26. DEP Average HDD Experienced by Treatment and Comparison Groups

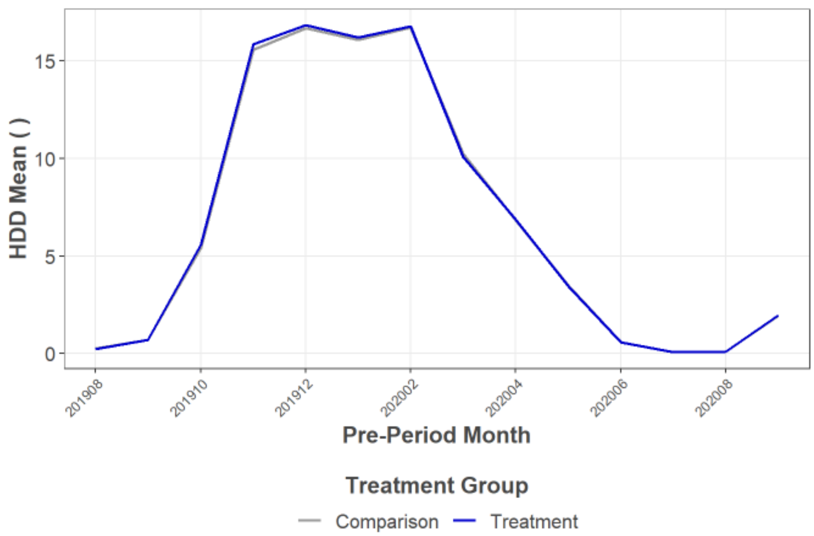

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Figure 27. DEC Average CDD Experienced by Treatment and Comparison Groups

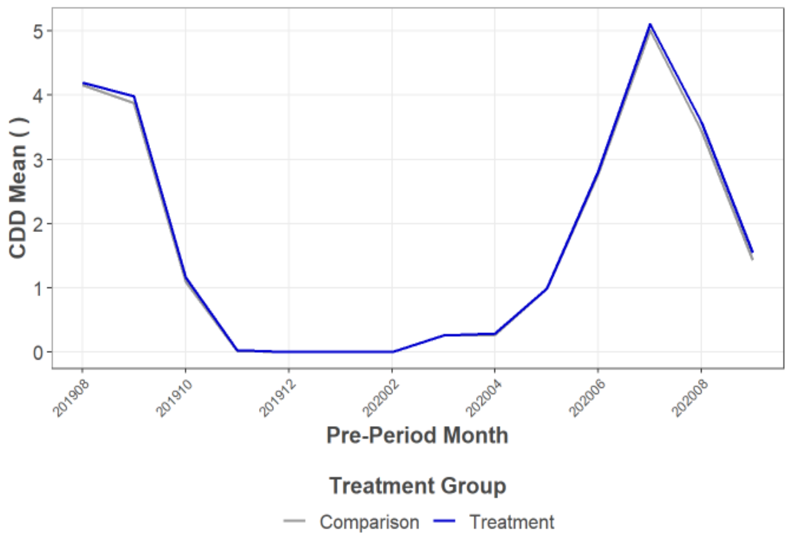
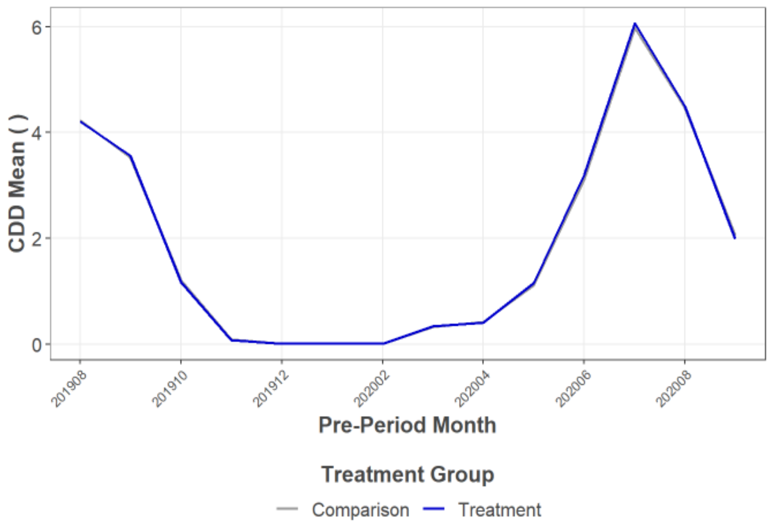


Figure 28. DEP Average CDD Experienced by Treatment and Comparison Groups



HOUSEHOLD CHARACTERISTICS OF PARTICIPANTS

Table 34 shows a comparison of treatment and comparison group participants across core available housing characteristics. As shown in the table, matching led to closer alignment between treatment and comparison group accounts on energy consumption and maintained alignment on other observable characteristics.

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Table 34. Household Characteristics of Treatment and Comparison Groups

Comparison Area	Treatment Participants After Cleaning	Treatment Participants After Matching	Comparison Participants After Cleaning	Comparison Participants After Matching
DEC				
Average Pre-Period Daily Consumption (kWh)	41.8	42.4	43.5	41.1
Percent of Customers with Electric Heating Source	43%	43%	53%	50%
Percent of Customers with Electric Water Heating Source	53%	53%	61%	59%
DEP				
Average Pre-Period Daily Consumption (kWh)	45.0	45.6	47.6	46.7
Percent of Customers with Electric Heating Source	58%	59%	72%	69%
Percent of Customers with Electric Water Heating Source	64%	64%	74%	70%

MODEL SPECIFICATIONS

To estimate savings for the REA Program, Opinion Dynamics specified a LFER model in a pre-/post-design that incorporates weather and interaction terms that show the effect of weather in the post-installation period. The fixed effect for the model is set at the account level, which allows us to control for all household factors that do not vary over time. In the process of determining the appropriate model for the analysis, we specified a range of models from simple pre-post to more complex models incorporating a variety of terms and controls.

We judged our final models on several criteria. Primarily, we aimed to use a model that explained as much about changes in the dependent variable as possible. The most direct measure of this is the adjusted R-squared, which gives an estimate of how much the model explains of the difference between post-period usage and the baseline. We also compared Akaike Information Criterion (AIC) values of each model specification within the same sample. The AIC provides a measure of relative quality between models; a lower value indicates a relatively more efficient model. This method inherently incorporates explained variation as well as how many variables we use to achieve that level.

Equation 5 contains final model specification for DEC and Equation 6 contains final model specification for DEP. Notably, we chose to incorporate the water heating indicator in the DEC model in an effort to mitigate inequivalency between the treatment and comparison groups. For similar reasons, we incorporated electric heat indicator in the final DEP model.

Equation 5. DEC Final Model Specification

$$ADC_{it} = B_h + B_1 TreatPost_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_{4-16} MonthDummies_t + B_{17} HDDElectricWater + \varepsilon_{it}$$

Where:

ADC_{it} = Average daily consumption (in kWh) for the billing period

$TreatPost$ = Indicator for treatment group in post-installation period (coded “0” in the pre-participation period, coded “1” in post-installation period)

HDD = Average daily heating degree days from NCDC

CDD = Average daily cooling degree days from NCDC

B_h = Average household-specific constant

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B_1 = Main program effect (change in ADC associated with being a participant in the post-installation program period)

B_2 = Increment in ADC associated with one-unit increase in HDD

B_3 = Increment in ADC associated with one-unit increase in CDD

B_{4-16} = Increments in ADC associated with each calendar month, excluding February

B_{17} = Presence of electric water heating system

ε_{it} = Error term

Equation 6. DEP Final Model Specification

$$ADC_{it} = B_h + B_1 TreatPost_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_{4-16} MonthDummies_t + B_{17} HDDElectricHeat + \varepsilon_{it}$$

Where:

ADC_{it} = Average daily consumption (in kWh) for the billing period

$TreatPost$ = Indicator for treatment group in post-installation period (coded "0" in the pre-participation period, coded "1" in post-installation period)

HDD = Average daily heating degree days from NCDC

CDD = Average daily cooling degree days from NCDC

B_h = Average household-specific constant

B_1 = Main program effect (change in ADC associated with being a participant in the post-installation program period)

B_2 = Increment in ADC associated with one-unit increase in HDD

B_3 = Increment in ADC associated with one-unit increase in CDD

B_{4-16} = Increments in ADC associated with each calendar month, excluding February

B_{17} = Presence of electric heating system

ε_{it} = Error term

Table 35 displays coefficient outputs for the DEC and DEP models. All models show a reduction in electricity use after customers participated in the REA Program, controlling for weather and time. The results are statistically significant.

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Table 35. Final Model Coefficients

Variable	DEC		DEP	
	Estimate	Significant (p<0.05)	Estimate	Significant (p<0.05)
treat_post	-1.5302296	Yes	-1.1760623	Yes
HDD	0.0261169	No	0.2056507	Yes
CDD	4.2361134	Yes	3.5712149	Yes
February	-1.4585092	Yes	-0.4813293	Yes
March	-3.9432912	Yes	-5.0477281	Yes
April	-5.2259412	Yes	-5.8366941	Yes
May	-2.6304204	Yes	-1.3371286	Yes
June	4.404955	Yes	6.5657943	Yes
July	5.2915076	Yes	9.5094635	Yes
August	5.88918	Yes	9.3393462	Yes
September	-0.5190759	No	3.2545103	Yes
October	-6.4094461	Yes	-3.5968045	Yes
November	-4.4014041	Yes	-2.6413572	Yes
December	0.7113194	Yes	0.4958609	Yes
hdd:electric_water	1.3002917	Yes	1.507034	Yes

SAVINGS ESTIMATION

The LFER model results presented in the section above show a statistically significant reduction in electric consumption for both jurisdictions. Table 36 shows an estimate of the average daily savings associated with the program by jurisdiction. These values reflect actual savings under actual weather conditions observed in the post period.

Table 36. Modeled Savings Estimates

Input	DEC	DEP
Modeled Treatment Participants	5,138	3,025
Average Daily Modeled Baseline (kWh)	43.13	47.04
Average Daily Modeled Savings Estimate (kWh)	1.53	1.18
Standard Error	0.11	0.16
t	72.40	72.69
P>[t]	0.00	0.00
Adjusted R-squared	0.74	0.74
90% Confidence Interval – Lower Bound	1.35	0.92
90% Confidence Interval – Upper Bound	1.71	1.43

To better facilitate comparisons of program performance, we also show savings here as a percentage of energy saved with respect to the modeled baseline. The baseline usage is calculated using the coefficients from the model. This calculation shows the energy that customers would have used on average if the program equipment had not been installed. To estimate the percent savings from baseline energy consumption, we divide the change in daily electricity use for the program by the mean baseline ADC to arrive at the percentage savings. We annualized first-year savings by multiplying the daily savings estimate by 365 days. The annualized value represents the average annual first-year savings. Table 37 shows the average annual baseline consumption per participant, average per household annual

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savings, and savings as a percentage of baseline consumption. We used these values to determine the overall program-level savings, which are reported in the body of the report.

Table 37. Estimated Annual Savings from Consumption Analysis

Input	DEC	DEP
Average Annual Baseline Energy Consumption per Participant (kWh)	15,742	17,171
Average per Participant Ex Post Net Annual Savings (kWh)	559	429
Average per Participant Savings Percentage	3.5%	2.5%

In addition to scrutinizing modeling outputs, Opinion Dynamics also explored and assessed the reasonableness of the modeled savings estimates relative to the other evaluations, including previous evaluations of the REA program in the same jurisdictions, as well as other jurisdictions, as well as other available data, such as participation and weather data. More specifically, we performed the following steps, all amounting to a thorough assessment of the savings reasonableness:

- Comparison of the savings estimates against previous evaluations
- Assessment of the savings estimates against participation and weather data
- Assessment of the savings estimates against participant baseline consumption data
- Assessment of the savings estimates against available data on participant household characteristics and installation practices.

Comparison of Savings Estimates Against Previous Evaluations.

Table 38 compares energy savings estimates developed as part of the current evaluation and compares them to the ones developed as part of the previous evaluation round for the same jurisdictions. We also include energy savings estimates for the recently evaluated REA program in the DEI jurisdiction for additional context. As can be seen in the table below, current DEP energy savings are considerably lower than the ones derived as part of the previous evaluation. Compared to DEC, the decline in the DEP savings is considerably steeper than the other jurisdictions, without a commensurate change in the baseline usage.[17] They are also considerably lower than savings from the recently completed DEI evaluation.

Table 38. Energy Savings Estimates from Previous Evaluations

Jurisdiction	Avg. Yearly Participant Savings (kWh)	Evaluation Period	Annual Baseline Usage (kWh)	Savings/ Baseline Usage (%)
DEC – current	559	9/2020 – 8/2021	15,742	3.5%
DEC – previous	694	5/2016 – 4/2017	17,385	4.0%
DEP – current	429	9/2020 – 8/2021	17,171	2.5%
DEP – previous	1,095	4/2016 – 3/2017	18,177	6.0%
DEI – previous	592	10/2020 – 6/2021	18,090	3.3%
DEI – previous	1,134	5/2016 – 3/2018	18,487	7.1%

[17] While we do not expect energy savings and baseline consumption to be linearly related, energy savings and baseline consumption are usually positively correlated. Furthermore, similar levels of baseline consumption can be indicative of the similarities of the program treated housing stock.

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Assessment of the Savings Estimates Against Participation and Weather Data

We explored the incidence of the various program measure installations in DEC and DEP jurisdictions over the program period under evaluation to explore whether differences in the incidence and quantity of installed measures can explain the difference in modeled savings estimates. Table 39 compares the incidence of measure installation between DEC and DEP jurisdictions. As can be seen in the table, virtually all measures are installed more frequently in DEP as compared to the DEC jurisdiction, which is contrary to the modeled outputs. Furthermore, aside from 11-watt LEDs, of which more on average are installed in DEC-participating homes vs. DEP-participating homes, the average measure quantity is generally the same across the two jurisdictions. These results are inconsistent with the modeled savings estimates.

Table 39. Incidence of Measure Installation and Average Number of Installed Measures

Measures	Incidence of Measure Installation		Average Number of Installed Measures Per Participant	
	DEC	DEP	DEC	DEP
11 Watt LED - Recessed	6%	7%	8.4	7.7
Additional 9 Watt A-Line LED	26%	32%	5.0	5.1
5 Watt LED - Candelabra	11%	15%	7.4	7.5
6 Watt LED - Globe	7%	8%	8.6	8.2
Handheld Showerhead (Electric)	2%	5%	1.3	1.3
Additional Bathroom Faucet Aerator (Electric)	10%	14%	1.9	1.9
Pipe Insulation (Electric)	13%	16%	6.3	6.0
Smart Thermostat (Cooling Only)	2%	1%	1.3	1.4
Smart Thermostat (Electric Heating and Cooling)	1%	2%	1.2	1.3

It is possible that milder or harsher weather in the post-period can lead to differing savings. To that end, we compared average weather in terms of CDD and HDD between DEC and DEP. Figure 29 shows weather comparisons. As can be seen in the figure, DEP participants experienced a slightly hotter post-period summer and a very similar winter. These results are contradictory to the DEP modeled estimates being lower than DEC's, as we would expect a hotter summer to result in more opportunities to realize energy savings from weather sensitive measures.

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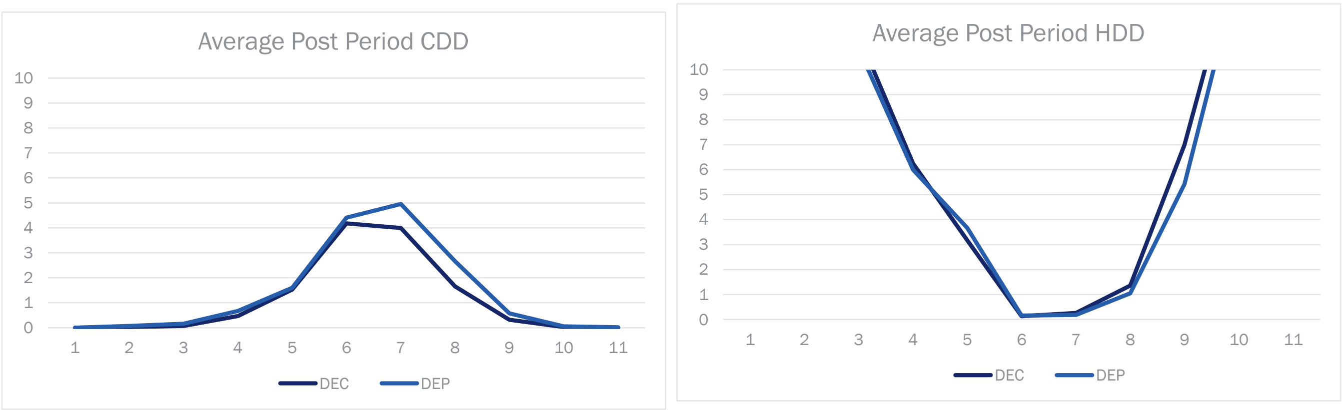
Figure 29. Average Post-Period Weather



Assessment of the Savings Estimates Against Participant Baseline Consumption Data

In our experience evaluating energy efficiency program savings, higher baseline usage is generally positively correlated with higher energy savings. That is not surprising, as higher baseline consumption can signal opportunities for energy conservation. With this observation in mind, we compared baseline usage of DEC and DEP participants. As presented in Table 37 above, DEP participant energy usage is 1,429 kWh or 9% higher than DEC participant energy usage.

Assessment of The Savings Estimates Against Available Data on Participant Household Characteristics and Installation Practices

As a final step in the process of exploring the differences in the modeled savings estimates, we explored measure installation and persistence[18] as well as other available household characteristics. Our review found little difference in in-service rate (ISR) between the two jurisdictions (Table 40).

Table 40. Measure In-Service Rate

Measure Type	DEC ISR	DEP ISR
Kit Measures		
Standard A-line LED 9W (2020)	88%	89%
Candelabra LED 5W (2021)	58%	55%
Low Flow Showerhead	41%	46%
Faucet Aerator (kitchen and bathroom)	53%	58%
Switch/Outlet Seal	64%	56%
Weather Stripping	39%	51%
Pipe Insulation	100%	100%
Discounted Measures		
Recessed LED 11W	83%	84%
Candelabra LED 5W	87%	95%
Globe LED 6W	93%	87%
Smart Thermostat	93%	100%
Specialty Showerhead	83%	94%

[18] We leveraged survey data collected as part of ou93%r evaluation for this assessment.100%

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Homes with electric heating and water heating systems present a greater potential for deeper energy savings through the program than homes with gas heating and water heating systems. As presented in Table 33, considerably more DEP participants have electric heating systems than DEC participants (58% vs. 43%). Similar is true for water heating systems (64% vs. 53%). This is contrary to the results from the DEP consumption analysis.

Based on the additional exploration steps described above, our assessment of the modeled DEP savings estimates is that the point estimate does not adequately or reasonably reflect the anticipation effects of the energy conservation actions performed as part of the program. As such, we used DEC-modeled savings estimates for DEP.

Table 41. Final Annuals Savings

Jurisdiction	Average per Participant Ex Post Net Annual Savings (kWh)
DEC	559
DEP	559

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APPENDIX B. FINAL DEEMED SAVINGS REVIEW MEMORANDUM

Embedded into this appendix is the DEC and DEP REA Program Final Deemed Savings Review Memorandum.

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Deemed Savings Rev

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APPENDIX C. NET-TO-GROSS METHODOLOGY

In this section, we detail the free-ridership (FR) algorithms used in this evaluation. We used one algorithm for LED lighting FR and a separate algorithm for all other program measures (including the assessment itself). We chose to use a separate LED FR algorithm to ensure consistency across Duke Energy program evaluations. Specifically, we chose to adopt the LED FR battery used to evaluate the Residential Lighting Program and we describe this approach below.

LED FREE-RIDERSHIP ALGORITHM DESCRIPTION

Participants of the Residential Energy Assessment (REA) Program received free LEDs in starter kits as well as free additional LEDs (during 2020 only). Participants also had the option of purchasing discounted specialty LEDs. As such, we asked participants questions about their purchase behaviors and decisions in the absence of the free LED kit offering. If they would have purchased the same level of efficiency, then these participants were considered free-riders. Figure 30 provides details of the FR algorithm. Blue boxes in the graphic are questions used in the calculation of the FR score, grey boxes are validation and consistency check questions, and green boxes are FR calculations.

We first asked participants what they would have purchased the next time they needed light bulbs if they had not received free LEDs in their energy efficiency starter kit. We included retail LED pricing as part of the question to make sure participants provided responses with consideration of LED costs. Participants who said they would have purchased incandescent bulbs, halogens, or the lowest-cost light bulb option were classified as non-free-riders. Participants who said that they would have purchased LEDs received follow-up questions asking about the timing and the quantity of the counterfactual LED purchase. Participants who reported they would have purchased a mix of products in the absence of the program received follow-up questions exploring the mix and validating respondent choices of the products in the mix.

Finally, as part of the FR algorithm, we explored installation patterns of program-provided LEDs and gave the program additional credit in cases where it motivated customers to replace working, less-efficient products instead of waiting for those bulbs to burn out. By encouraging participants to replace working light bulbs, the program accelerates energy savings and therefore deserves a credit. In cases where participants said that they would have waited for their bulbs to burn out in the absence of the program, we gave the program the credit depending on the number of working light bulbs that program-provided LEDs replaced.

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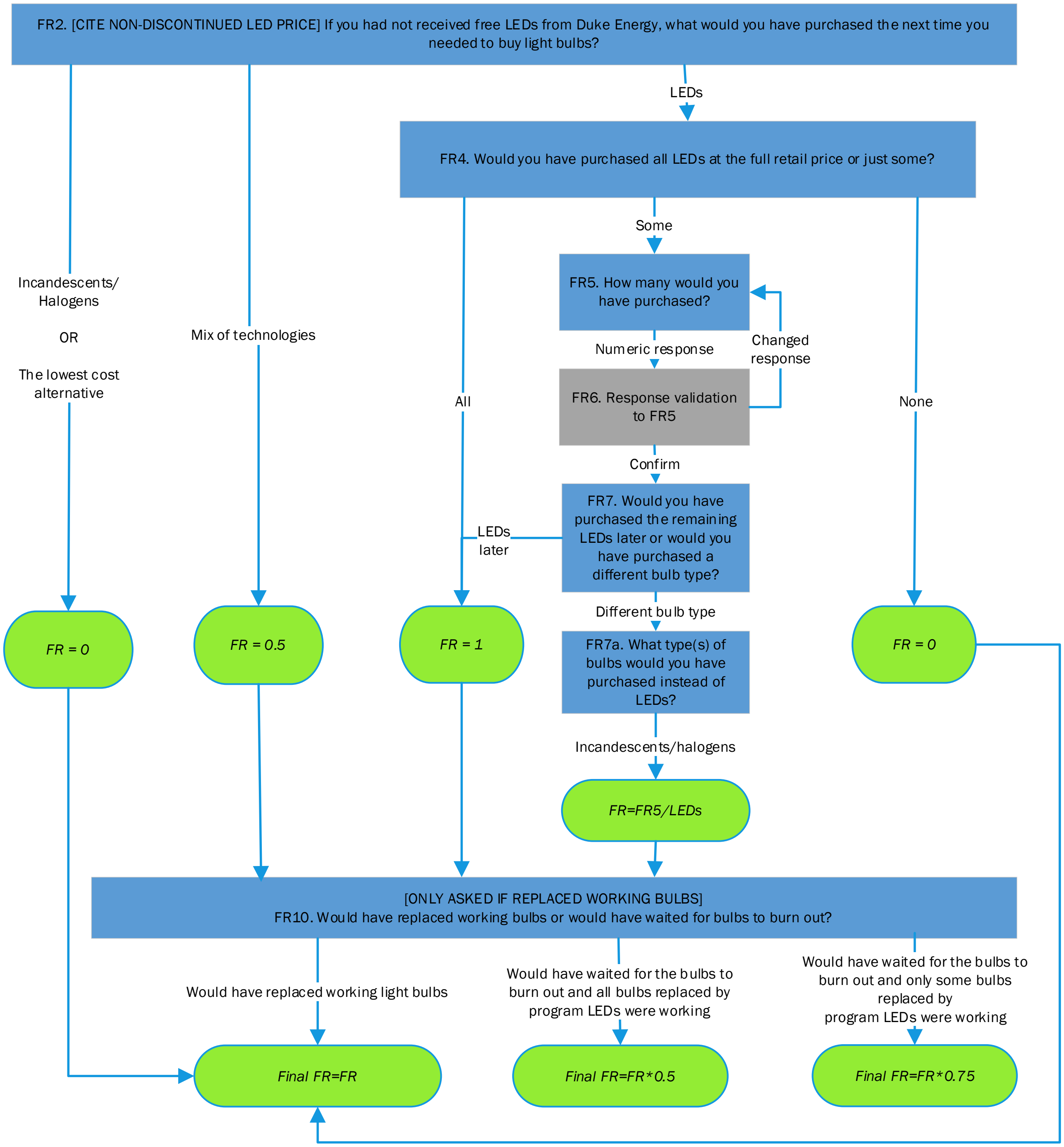
Figure 30. LED Free-Ridership Algorithm



As part of calculating the FR, we made reasonable imputations where participant responses were missing or contradictory.

Using the above-outlined algorithm, we calculated an FR rate for each respondent. We weighted the participant-level FRs by the quantity of each measure and summed up the weighted FRs to determine the final FR rate for each measure.

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ALL OTHER MEASURES FREE-RIDERSHIP ALGORITHM DESCRIPTION

Evaluations of energy efficiency programs typically measure the program influence on what customers install, when they install it, and how much they install. As such, the FR algorithm used for all other program measures combines the estimates of each of these concepts:

- **Efficiency:** Did the program intervention cause participants to install a higher-efficiency measure than they otherwise would have?
- **Quantity:** Did the program intervention cause participants to install more of the equipment than they would have if they had to pay full retail price?
- **Timing:** Did the program intervention cause participants to install equipment in place of working, less-efficient equipment rather than waiting for the equipment to stop functioning?

To assess FR for all other program measures (including the energy assessment itself), the evaluation team used a multiplicative algorithm based on the likelihood the participant would have installed the measure on their own within the next year (PI), adjusted by the program's influence on measure quantity (PQ) and installation timing (PT).

Table 42 shows how responses to the FR questions were scored for non-lighting measures (i.e., faucet aerators, low-flow showerheads, outlet covers, and weatherstripping).

Table 42. FR Algorithm Framework

Question Type	Algorithm Component[A]	Survey Questions	Response and Scoring[B]
PI	If you had not received free [measure name] during the energy audit, how likely is it that you would have installed any [measure name] on your own within the next year?	FA4, SH7, G5, W3, PW3, DSH7, N3	PI = x ÷ 10 DK/Ref: Removed from FR analysis
PQ	If you had not received free [measure name] during the energy audit, would you have installed the same number or fewer [measure name] than were installed?	FA5, SH8, G6, W4, PW4, DSH8	None = 0 Fewer = 0.5 The same = 1 More = 1 DK/Ref = Removed from FR analysis
P_ST[C]	Without the program, which of the following would you have replaced your thermostat with—a manual, a programmable thermostat, and/or a smart thermostat?	N4	Manual thermostat = 0 Programmable thermostat = 0 Smart thermostat = 1
PT	If you had not received free [measure name] during the energy audit, when would you have installed [measure name] on your own?	FA6, SH9, G7, W5, PW5, DSH9, N5	Same time = 1 Within 6 months = 0.5 Within a year = 0.33 More than a year = 0 DK/Ref = Removed from FR analysis

[A] FA = Faucet aerators, SH = Showerheads, G = Outlet seals, W = Weatherstripping, PW = Pipe wrap, DSH = Discounted handheld showerhead, N = Smart thermostat, DK/Ref = Don't know/Refused.

[B] Scalar 0 to 10; 0=not at all likely, 10= extremely likely

[C] For smart thermostats, instead of quantity, we asked what type of thermostat the participant would have purchased/installed without the program. Those who indicated that they would have purchased/installed a smart thermostat were given a score of 1, while those who indicated that they would purchase either a manual or programmable thermostat were given a score of 0 for this free-ridership component.

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To calculate the measure-level FR score, we multiplied the three components together as shown below:

Equation 7. Free-Ridership Formula

$$FR = PI \times PQ \times PT$$

An FR score of 1 means the participant is a full free-rider (the program gets no credit for the measure), while an FR score of zero means the participant is not at all a free-rider (the program gets full credit for the measure). Program-level FR for each measure is calculated as the average across all participant-level FR scores.

SPILLOVER

Spillover (SO) represents energy savings from additional energy-efficient equipment (expressed as a percentage of total program savings) that resulted from program participation, but that did not receive program financial support. While SO can result from a variety of measures, it is not possible to ask about a large number of potential SO measures on a survey due to the need to limit its length. Thus, the evaluation team chose to focus on equipment purchases that participants would reasonably take following their program participation and would do so without additional program support.

The participant survey included a series of questions to assess overall SO among program participants. To determine SO, we asked two main questions:

- Did the participant make any additional improvements to reduce household energy consumption since participating in the program?
- If the respondent indicates making additional improvements (or changing behaviors): How would the participant rate (on a scale from 0 to 10) the influence their experience with the program had on their decision to make these improvements?

In addition to asking participants to rate the program influence, the evaluation team requested participants provide a rationale for their rating. We attributed SO for all respondents who gave a program influence score of 7 or higher. These respondents were asked a series of follow-up questions to assess the efficiency of measures.

To estimate the SO rate, we estimated savings for each SO measure using engineering algorithms and assumptions. We determined the program-level SO rate by dividing the sum of measure-level SO savings by the evaluated gross savings achieved by the sample of participants who received SO questions.

Equation 8. Spillover Rate Formula

$$Spillover\ Rate = \frac{Spillover\ Savings}{Evaluated\ Gross\ Savings\ in\ the\ Respondent\ Sample}$$

NET-TO-GROSS RATIO

To calculate measure-level NTGRs, we combined the FR and SO rates using the following equation:

Equation 9. NTGR Formula

$$NTGR_{measure} = 1 - FR_{measure} + SO_{program}$$

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