APPENDIX H

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Duke Energy Ohio

2015–2016 Neighborhood Energy Saver Program Evaluation Report

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Opinion Dynamics

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1. Evaluation Summary

1.1 Program Summary

Duke Energy Ohio's (DEO) Neighborhood Energy Saver (NES) program[1] provides one-on-one energy education, on-site energy assessments, and energy conservation measures at no cost to customers. The program is available to active DEO account holders who are individually metered homeowners/tenants living in predetermined income-qualified communities. Neighborhoods selected to participate in this program must have at least 50% of households with incomes equal to or less than 200% of the federal poverty level. Each household is limited to a one-time receipt of energy efficiency measures through the NES program.

The NES program aims to serve at least 1,339 customers annually within the predetermined communities throughout the DEO service territory. The goal is to offer persistent energy savings to these customers through the direct installation of energy-saving measures and by educating customers about other ways that they can reduce their energy use. When possible, the program works with community leaders to promote the program and maximize the number of customers in each neighborhood benefiting from the program.

1.2 Evaluation Objectives and High-Level Findings

The DEO NES program evaluation comprises an impact evaluation and a process evaluation. The objectives of the 2015–2016 program evaluation are to:

- Verify deemed savings estimates through a review of measure assumptions and calculations
- Verify measure installation and persistence
- Estimate program energy savings (kWh), summer and winter peak demand (kW) savings, and realization rates
- Identify barriers to participation in the program and recommend strategies for addressing those barriers
- Identify program strengths and the potential for increasing the average per-household savings attributable to the program
- Identify ways that DEO may be able to improve the NES program in the future

To achieve these objectives, Opinion Dynamics completed a number of data collection and analytic activities, including interviews with program staff, a participant survey, an analysis of the survey results, an analysis of program-tracking data, a deemed savings review, an engineering analysis, and a billing analysis. The program period under evaluation is January 1, 2015 through December 31, 2016.[2]

Overall, the DEO NES program performed well in 2015 and 2016. In 2015, the program served 1,362 unique participants and achieved approximately 30% penetration, meeting program participation goals. In 2016, the program served 1,314 unique participants and achieved approximately 72% penetration, falling within the allowable 10% deviation relative to its participation goal and exceeded its neighborhood penetration goal.

[1] From 2013 to 2015, the program was referred to as the Residential Neighborhood Program (RNP). From 2016 forward, the program in DEO territory, and all other Duke Energy territories in which the program is implemented, is referred to as the Neighborhood Energy Saver (NES) program. For simplicity, the program is referred to as the NES program throughout this report.

[2] In 2015, the NES program was implemented by GoodCents. In 2016, it was implemented by Honeywell Building Solutions (Honeywell).

Engineering Analysis

As part of the impact evaluation, we conducted an engineering analysis to provide insight into how each program measure contributes to overall program savings. The engineering analysis also allows us to develop a ratio of overall kW to kWh savings, which we then apply to the net energy (kWh) savings from the billing analysis to determine evaluated net demand (kW) savings for the program. Table 1-1 and Table 1-2 present the total gross energy and demand savings for each measure installed through the program and the estimated individual measure contribution to the overall energy (kWh) savings from the engineering analysis. We present impacts separately for the two program years under study.

Table 1-1. Total Measure-Level Gross Energy Savings Results from Engineering Analysis

Measure	GoodCents (2015)		Honeywell (2016)	
	Energy (MWh)	Percent of Total MWh	Energy (MWh)	Percent of Total MWh
CFL	269	47%	236	43%
Infiltration Reduction	81.4	14%	76.2	14%
Water Heater Pipe Wrap	78.6	14%	55.4	10%
Efficient Faucet Aerator	58.6	10%	66.8	12%
Efficient Shower Head	46.6	8%	61.6	11%
HVAC Filters	33.2	6%	34.7	6%
Hot Water Temp Setback	6.85	1%	6.20	1%
Water Heater Blanket	1.34	0%	11.9	2%
Total	**576**	**100%**	**549**	**100%**

* Totals may not sum due to rounding of individual measure savings.

Table 1-2. Total Measure-Level Gross Demand Savings Results from Engineering Analysis

Measure	GoodCents (2015)				Honeywell (2016)			
	Summer Coincident Demand		Winter Coincident Demand		Summer Coincident Demand		Winter Coincident Demand	
	kW	%	kW	%	kW	%	kW	%
Infiltration Reduction	37.5	37%	18.2	28%	35.1	37%	17.1	27%
CFL	36.8	37%	17.4	27%	32.4	34%	15.3	24%
HVAC Filters	10.4	10%	7.2	11%	10.9	12%	7.6	12%
Water Heater Pipe Wrap	8.96	9%	8.96	14%	6.32	7%	6.32	10%
Efficient Faucet Aerator	3.32	3%	6.64	10%	3.82	4%	7.65	12%
Efficient Shower Head	2.55	3%	5.09	8%	3.37	4%	6.74	11%
Hot Water Temp Setback	0.78	1%	0.78	1%	0.71	1%	0.71	1%
Water Heater Blanket	0.15	0%	0.15	0%	1.35	1%	1.35	2%
Total*	**100**	**100%**	**64**	**100%**	**94**	**100%**	**63**	**100%**

* Totals may not sum due to rounding of individual measure savings.

Billing Analysis

Program net energy savings for the DEO NES program are derived from the results of our billing analysis. The billing analysis provides average per-household net energy savings. Table 1-3 presents the net savings results of our billing analysis on an annual per-participant basis, as well as net annual program savings. Net savings from the billing analysis include savings from measures installed by program representatives, as well as savings from any additional behavioral changes and participant spillover attributable to the program. For this analysis, we applied a robust method that used a comparison group of future DEO NES program participants to create a baseline of what would have occurred in the absence of program participation. Demand savings are calculated from the ratios of engineering analysis kW to kWh savings, which are applied to the billing analysis net energy (kWh) savings.

Table 1-3. Net Participant and Program Impact Results from Billing Analysis

Net Annual Savings Per Participant			Net Annual Program Savings		
Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)	Energy (kWh)	Summer Coincident Demand (kW)	Winter Coincident Demand (kW)
303	0.052	0.034	810,828	139	91

Based on the billing analysis, participants in the NES program saved 3.2% of their baseline energy usage after participating in the program. Per-participant annual net energy savings from the billing analysis (303 kWh) are 109 kWh lower than those estimated during the previous evaluation (412 kWh[3]), which was used as the planning assumption for the 2015 and 2016 program years. Evaluated energy and demand savings per treated household are, therefore, lower than anticipated, resulting in a 74% realization rate.

Senate Bill 310 Compliance

To support compliance with Ohio Senate Bill 310 (SB 310), Table 1-4 provides the energy and peak demand savings claimable under SB 310. Per SB 310, DEO will claim 412 kWh of energy savings and 0.13 kW and 0.14 kW of peak summer and winter demand savings, respectively, per household for the 2015-2016 program years. These values are the higher of the ex ante and ex post savings values, based on the billing analyses conducted for the current and the previous evaluations.

Table 1-4. Summary of Impacts for SB 310 Compliance

Per Household Impacts (2015-2016)	
Energy Savings (kWh) per Household	412
Summer Coincident Savings (kW)	0.13
Winter Coincident Savings (kW)	0.14

Process Evaluation

Our process evaluation sought to answer several questions related to NES participant satisfaction and the overall effectiveness of the program, specifically the educational component. We present the full results of the process evaluation in Section 6; however, we summarize the key findings from this portion of the evaluation below.

- Participants were also highly satisfied with the program:

[3] Source: Process and Impact Evaluation of the 2013-2014 Residential Neighborhood Program in Ohio, Prepared for Duke Energy by TecMarket Works, February 2015.

- Seventy-four percent of 2015 participants and 81% of 2016 participants said that they were satisfied with the program overall; and
- Eighty-seven percent of 2015 participants and 86% of 2016 participants said that they were satisfied with the program representative who visited their home.

- The educational component of the program is highly successful and participants report taking energy-saving action after participating:
  - Eighty-four percent of participants said that they received in-person recommendations from program staff and 67% of those participants found that information useful in helping them to save energy; and
  - Seventy-seven percent of 2015 participants and 83% of 2016 participants said they were motivated to reduce their energy use after participating in the program.

1.3 Evaluation Recommendations

Opinion Dynamics has the following recommendations for maintaining and improving program performance and overall savings. We include more details on these recommendations in Section 6 and throughout this report.

- **Offer specialty lighting.** In addition to offering LEDs, which NES participants began receiving in 2017, the program should assess opportunities for specialty lighting products. Savings opportunities from replacing bulbs in lower-use sockets are limited given that these sockets tend to have lower hours of use. However, there may be opportunities to replace specialty bulbs with more-efficient options. Specifically, 24% of 2015 and 2016 participants did not have some bulbs replaced with CFLs during the visit. Of these participants, fifty-eight percent attributed this to the program representative not having the correct bulb during their home visit, and 27% said that the program CFL would not have worked with a dimmer switch.
- **Investigate potential savings and costs of additional measures frequently offered through income-qualified programs.** From 2015 to 2016, the portion of the program's energy savings coming from CFL replacements fell from 47% to 43% respectively. As savings opportunities from efficient lighting measures continue to decrease, additional program offerings would allow the program to maintain consistent levels of energy savings per-household. The program should consider the feasibility of adding other measures commonly offered by income-qualified programs, such as advanced power strips and programmable thermostats, to diversify and increase program savings.
- **Investigate the feasibility of refining neighborhood targeting.** When compared to NES participants in other Duke Energy service territories, DEO NES participants from 2015 and 2016 have the lowest average baseline energy consumption. While the 3.2% savings rate by DEO NES participants is similar to other jurisdictions, their overall average savings is lower. The types of households and housing stock in the 2015 and 2016 participant population may be responsible for their lower overall energy savings. Our research suggests that these participants had lower central air conditioning, electric heat, and electric water heating penetration than neighborhoods targeted in other Duke Energy service territories.

  DEO program staff currently leverage MapPoint software to identify neighborhoods with eligible customers based on income levels. We recommend for consideration, if feasible, augmenting targeting efforts to include average energy consumption as an additional criterion when selecting neighborhoods that also meet the NES income threshold. This will allow program staff to continue to reach a broad range of DEO customers, while also helping to maximizing potential energy savings from NES participants.

- **Continue to leverage a canvassing approach to support high penetration rates.** From 2013 through 2015, NES program implementers had goals for the total number of customers served through the program each year. Beginning in 2016, Duke Energy set an additional goal to achieve 70% penetration in each neighborhood selected. To address this additional goal, Honeywell staff canvassed each street within the selected neighborhoods, performing assessments and installations when customers were available and leaving behind their contact information via door hangers when they were not. This canvassing approach achieved a much higher penetration rate than GoodCents' appointment-driven approach.
- **Continue to focus on energy education.** According to the participant survey, the program's energy education component increases participant knowledge about energy savings practices and likely contributes to energy savings. Survey respondents reported completing a suite of energy savings behaviors promoted by the program. Program staff should continue to promote this aspect of the program.
- **Track water heater temperature setbacks.** The two program implementers tracked water heater temperature setbacks differently in 2015 and 2016. Specifically, in 2015, the measure was labeled "Water Heater Temperature Adjustment," while for 2016, it was labeled "Water Heater Temperature Check," but did not track hot water tank temperature set point adjustments. We recommend explicitly tracking when the program representatives makes these adjustments moving forward.

2. Program Description

2.1 Program Design

Duke Energy Ohio's (DEO) Neighborhood Energy Saver (NES) program[4] is a direct-install program that employs a neighborhood canvassing approach to drive participation. The goal is to offer persistent energy savings to income-qualified customers through the direct installation of energy-saving measures. The program also offers an extensive educational component through neighborhood launch events and one-on-one education that provides participating customers with information on the measures that they received and additional suggestions on ways to lower energy use. The program provides the measures and services at no cost to customers and collaborates with existing neighborhood organizations to promote the program and maximize the number of customers benefiting from the program.

Neighborhoods can be selected to participate in the program if at least 50% of the households in the community have incomes equal to or less than 200% of the federal poverty level. The program aims to reach at least 1,339 customers each year in two to three pre-identified communities throughout the DEO service area. Participating households are limited to a one-time receipt of energy efficiency measures through the program. During 2015, program administrators required a neighborhood to be between 100 and 1,000 households. In 2016, program requirements changed somewhat to specify that a neighborhood contain between 500 and 1,500 households. Duke Energy administers this program with a similar design throughout its service territories and has done so since 2013.

2.2 Program Implementation

GoodCents implemented the DEO NES program from 2013 to 2015. Beginning in December 2015, Honeywell Building Solutions (Honeywell) took over implementation of the NES program, in partnership with Duke Energy program staff. The program implementer performs all assessments and installations, though DEO program staff are heavily involved in the selection of specific neighborhoods based on program eligibility criteria.

Prior to participating in the program, residents in selected neighborhoods receive targeted mailings from the program that provide introductory information about how to participate; the benefits of participation; and a notice to keep an eye out for additional information from the program, including additional mailings and a community launch event. The implementation team organizes at least one community launch event in each targeted neighborhood, both to make residents aware of the program and to provide demonstrations of the measures that the NES program offers.

NES program implementers had goals for the total number of customers served through the program each year. In 2015, GoodCents encouraged customers to schedule specific times for their assessment and measure installation. The GoodCents contract expired the end of 2015, so starting in 2016, Honeywell became the installation vendor. The Honeywell staff had a different approach, canvassing each street within a selected neighborhood, performing assessments and installations when customers were available and leaving behind their contact information via door hangers when they were not, achieving a much higher penetration rate than GoodCents' appointment-driven approach.

[4] From 2013 to 2015, the program was referred to as the Residential Neighborhood Program (RNP). From 2016 forward, the program in DEO territory, and all other Duke Energy territories in which the program is implemented, is referred to as the Neighborhood Energy Saver (NES) program. For simplicity, the program is referred to as the NES program throughout this report.

The implementation team records measure installation information at each premise, which Duke Energy tracks in its program-tracking database. Based on recommendations from previous evaluations and best practices of this program in other Duke Energy service territories, in 2016, program representatives began to record the location in which they installed faucet aerators (kitchen or bathroom), along with housing characteristics, such as the type of heating system and the presence of central air conditioning. Finally, program staff left behind educational materials that explained the measures that they installed in each home, additional recommendations on how participants could save energy through behavioral changes, and information on other Duke Energy programs that may be of interest.

2.3 Program Performance

The program period under evaluation is January 1, 2015 through December 31, 2016. Over this time period, the program served 2,676 households in three neighborhoods. The program saved, on average, 303 kWh per household per year. Coincident demand savings per household were 0.052 kW in summer and 0.034 kW in winter.

3. Key Research Objectives

The objectives of the 2015–2016 DEO NES program evaluation are to:

- Verify deemed savings estimates through a review of measure assumptions and calculations
- Verify measure installation and persistence
- Estimate program energy savings (kWh), summer and winter peak demand (kW) savings, and realization rates
- Identify barriers to participation in the program and recommend strategies for addressing those barriers
- Identify program strengths and the potential for increasing the average per-household savings attributable to the program
- Identify ways that DEO may be able to improve the NES program in the future

4. Overview of Evaluation Activities

To answer the research objectives outlined in the previous section, Opinion Dynamics performed a range of data collection and analytic activities, including:

- Program staff interviews (n=2)
- A participant survey (n=126)
- A program materials and data review
- Impact analyses (including an engineering analysis and a billing analysis)
- Process analyses

In Sections 5 and 6, we provide more details on the methods and results of the impact and process analyses, respectively. Below, we summarize the scope and approach for the staff interviews, the program materials and data review, the deemed savings review, the billing analysis, and the participant survey. Each of these components supported either the impact or the process evaluations.

4.1 Program Staff Interviews

Opinion Dynamics conducted two interviews with the DEO NES program staff responsible for the administration of the program in 2015–2016. The in-depth interviews allowed us to discuss implementation of the NES program in Duke Energy's Ohio territory and to discuss differences between the NES program in Ohio and other Duke Energy territories. We also used these interviews to identify program successes, to discuss any difficulties in administering the program, and to determine any risks for the program achieving its goals. We also discussed the different implementation approaches of GoodCents and Honeywell, how they differed across the 2-year period, and the implications for the billing analysis.

4.2 Participant Survey

Opinion Dynamics implemented a computer-assisted telephone interviewing (CATI) survey with 2015 and 2016 NES program participants between January 5, 2017 and January 19, 2017. We completed a total of 126 interviews; the average length of the interviews was approximately 16 minutes. We attempted a census of all 2,107 participants from the beginning of 2015 through the third quarter of 2016, though several 2015 participants had since moved or their accounts were listed as inactive. Our team removed 85 records that had issues with phone numbers, 177 records that were on DEO's "Do Not Call" list, and 312 records that were listed as inactive accounts. We then attempted to contact all of the remaining 1,533 program participants; therefore, the concept of relative sampling precision does not apply to this effort. The response rate for this participant survey was 14%.

4.3 Program Materials and Data Review

DEO program administration staff provided Opinion Dynamics with information on the program. These data included the program marketing materials, program tracking databases, and other program documents—such as, NES implementation requirements, educational procedures, and contractors' on-site auditing and direct installation procedures. Each of these materials is further described below.

- **Marketing Materials.** Opinion Dynamics reviewed the leave-behind brochure, the customer survey booklet, the pre-participation program informational brochure, the leave-behind door hanger, the energy efficiency brochure about other Duke Energy programs, the introduction letter to the NES program and the informational session, examples of the presentation shown at the informational sessions, and postcards sent to participants with information about how to participate.
- **Program Databases.** The program staff provided Opinion Dynamics with program-tracking data for both 2015 and 2016. The databases provided us with information on the quantities, location (in some cases), and types of measures installed in each treated household. Additionally, Duke Energy began tracking other household and participation characteristics in 2016, such as heating fuel type and how the participant first heard about the program.
- **Program Documents.** The program documents that we reviewed included a presentation about the NES program design, on-site procedures from each implementation contractor, and statements of work between Duke Energy and the implementation contractors. We also reviewed the program evaluation report from the previous evaluation cycle (2013–2014).[5]

4.4 Deemed Savings Review and Engineering Analysis

Opinion Dynamics conducted a review of the deemed savings values and assumptions for each of the NES program measures. The source for 2015 and 2016 evaluated program savings is the billing analysis; however, we calculated evaluated demand savings using the ratio between energy and demand savings estimates from our engineering analysis. The primary goal of the deemed savings review is to develop updated savings algorithms and input assumptions that are consistent with standard industry practice and comparable with applicable Technical Reference Manuals (TRMs).

To conduct our deemed savings review, we performed the following steps:

- Reviewed the prior evaluation report, for the 2013–2014 program
- Reviewed all information received to date to decide if any of the current savings estimates or assumptions required updates
- Reviewed the latest Ohio (OH) and Indiana (IN) TRMs, along with other recently published studies where relevant, to determine if there was a need for additional updates

Our evaluation also relied on data from the CATI survey to confirm measure installation and persistence rates, which we combined with engineering estimates for each measure to develop estimated savings by measure group.

As part of our engineering analysis, we developed a ratio of overall kW to kWh savings, which we then applied to the net energy (kWh) savings from the billing analysis (see next subsection) to determine evaluated net demand (kW) savings for the program. Appendix C provides more detail on the methods used in the deemed savings review and engineering analysis.

[5] Process and Impact Evaluation of the 2013–2014 Residential Neighborhood Program in Ohio. Prepared for Duke Energy by TecMarket Works, February 2015.

4.5 Billing Analysis

Opinion Dynamics conducted a billing analysis to determine the net savings attributable to the NES in 2015 and 2016. We used a linear fixed effects regression (LFER) model to estimate the overall net ex post program savings. The model allowed us to control for all household factors that do not vary over time. The billing analysis used participants from both 2015 and 2016 as the treatment group, while the comparison group consisted of DEO customers in neighborhoods selected for participation in 2017. A summary of the billing analysis approach is provided in Section 5.3.1; a detailed description of the billing analysis methodology is presented in Appendix D.

5. Impact Evaluation

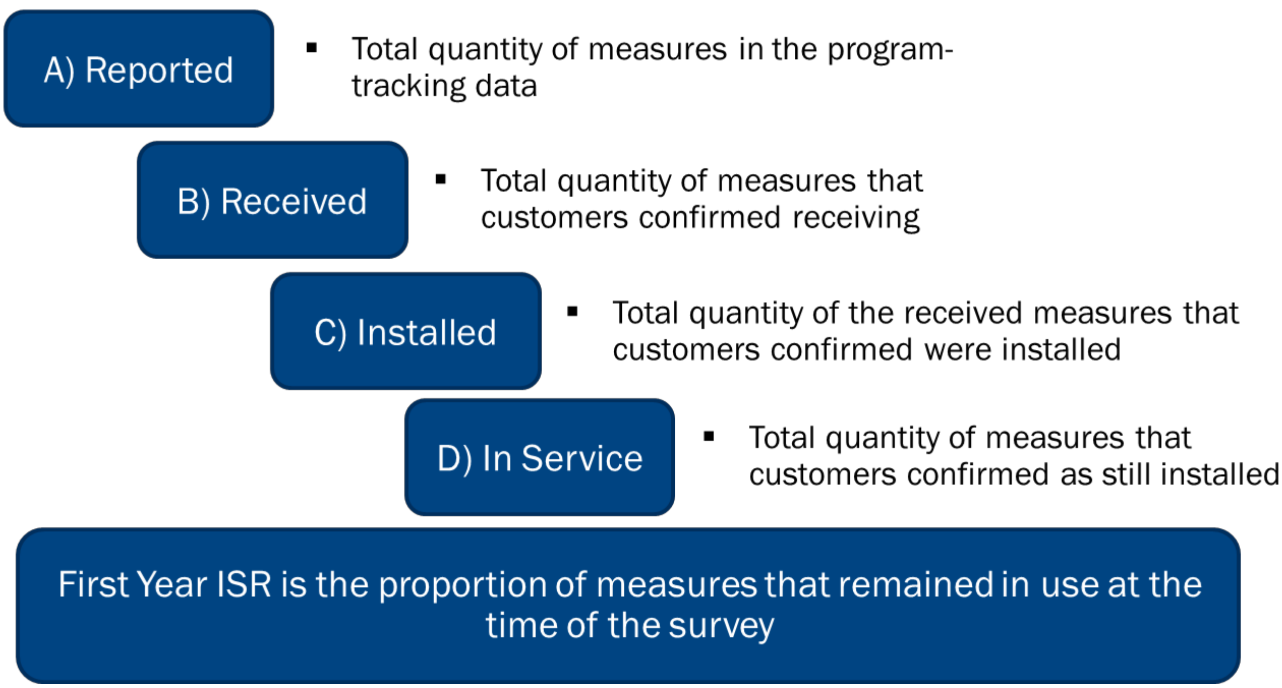
This section describes our methods used in and the results of the measure verification, engineering, and billing analyses.

5.1 Measure Verification

5.1.1 Measure Verification Methodology

The participant survey instrument includes questions designed to verify that participants received program measures and that those measures remain in place and are operational. Opinion Dynamics attempted to achieve a census of all program participants, and therefore the concept of relative sampling precision does not apply to the ISR estimates. Figure 5-1 outlines the method for deriving ISRs 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 verify the quantity of measures that were installed and remained in service at the time of the survey.

Figure 5-1. In Service Rate Components



Once participants provided each of the quantities described in Figure 5-1 we calculated the verification, installation, and persistence rates shown below for each participant and each measure they received. We then calculate the average of all three rates for each of the measure groups shown in Table 5-1. Finally, as shown in the equation below, we multiplied the average verification, installation, and persistence rates together to reach the first year ISR for each measure group.

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

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

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

$$\boldsymbol{First\ Year\ ISR} = (\mathbf{1})\ \boldsymbol{Verification\ Rate} \times (\mathbf{2})\ \boldsymbol{Installation\ Rate} \times (\mathbf{3})\ \boldsymbol{Persistence\ Rate}$$

In previous evaluations of the NES program in other Duke Energy service territories, Opinion Dynamics found that participants were unable to verify certain measures (e.g., water heater temperature setbacks, water heater tank and pipe wraps). For these measures, we assumed 100% for verification, installation, and persistence rates. Additionally, for some air infiltration measures, such as caulking or glass patch tape, participants are unable to verify installation, and we assumed that those measures remain installed. As such, we asked participants to verify receipt of air infiltration measures, but assumed 100% installation and persistence rates. As all NES measures are installed directly by program staff and these measures specifically are difficult to remove, we feel that these assumptions are reasonable for this type of program.

5.1.2 Measure Verification Results

The results of the measure ISR analysis showed relatively high ISRs for most measures in the NES program, as shown in Table 5-1. Similar to other Duke Energy service territories that offer the NES program, ISRs remained relatively high across both years and different measure groups. Additionally, because the program was implemented by two different contractors in 2015 and 2016, we calculated ISRs for each program year separately. While some of the differences between the two years may be due to implementation strategy, we also attribute differences between the two years to participants having more difficulty recalling the measures that they received in 2015 than they did recalling those received in 2016.

Table 5-1. ISRs for NES Program Measures by Year

Measure	GoodCents (2015)				Honeywell (2016)			
	Verification Rate	Installation Rate	Persistence Rate	ISR	Verification Rate	Installation Rate	Persistence Rate	ISR
CFL	91%	98%	85%	77%	96%	93%	97%	87%
Efficient Faucet Aerator	86%	92%	92%	73%	83%	97%	97%	78%
Efficient Shower Head	85%	100%	93%	80%	91%	97%	97%	85%
Hot Water Temperature Setback*	100%	100%	100%	100%	100%	100%	100%	100%
Water Heater Pipe Wrap*	100%	100%	100%	100%	100%	100%	100%	100%
Water Heater Blanket*	100%	100%	100%	100%	100%	100%	100%	100%
Infiltration Reduction**	100%	100%	97%	97%	88%	100%	99%	87%
Door Sweep	100%	100%	92%	92%	89%	100%	97%	86%
Weather Stripping	100%	100%	100%	100%	89%	100%	100%	89%
HVAC Filters	82%	95%	100%	78%	87%	91%	100%	79%

Note: Multiplying verification, installation, and persistence rates presented in this table may not equal ISRs due to rounding.

* Verification, installation, persistence, and ISRs are not verified based on the results of the survey and are assumed to be 100%.
** ISRs for infiltration reduction are the weighted average of all insulation measures. With the exception of weather stripping and door sweeps, infiltration measures are verified as a unit.

5.2 Engineering Analysis

5.2.1 Engineering Analysis Methodology

As part of our impact evaluation, Opinion Dynamics conducted an engineering analysis for each NES program measure installed in 2015 and 2016. Note that the billing analysis determines the net evaluated energy (kWh) impacts for the program; and the engineering analysis supplements the billing analysis by:

- Providing a ratio of demand savings (kW) to energy savings (kWh), which is then applied to the billing analysis net energy savings to calculate net evaluated demand savings
- Providing insight into the individual measure contributions to the overall program savings

We used several resources and assumptions to conduct our engineering analysis. We first reviewed the 2013–2014 evaluation, measurement, and verification (EM&V) report for the DEO NES program.[6] We then used both the OH TRM and the IN TRM to examine algorithms and assumptions where appropriate and used DEO-specific assumptions whenever possible. We prioritized the use of the OH TRM and the IN TRM whenever possible, as the inputs and assumptions are typically more applicable to DEO territory. The engineering analysis takes into consideration the measure in service rates (ISRs) estimated based on the participant survey to ensure that

[6] Ibid.

program-level savings estimates reflect savings for installed and operating measures only. We provide additional details and information on the engineering analysis in Appendix C.

5.2.2 Engineering Analysis Results

This section provides gross energy and demand savings estimates for each measure offered by the NES program in 2015 and 2016. Appendix C contains all detailed algorithms and assumptions used in the engineering analysis.

Table 5-2 provides the estimated gross per-unit energy and demand savings across the measures installed through the NES program, as determined through our engineering analysis. As described in Section 5.2, we based the measure-level savings on secondary research and applied NES program-specific assumptions on housing characteristics, such as the portion of homes using electricity for heating, cooling, and hot water heating.

Table 5-2. Engineering Analysis Deemed Savings Results

Measure	Quantity Units	Energy Savings (kWh)	Summer Peak Demand (kW)	Winter Peak Demand (kW)
9 Watt CFL	Bulbs	17	0.002	0.002
13 Watt CFL	Bulbs	25	0.003	0.003
18 Watt CFL	Bulbs	30	0.004	0.004
20 Watt CFL	Bulbs	28	0.004	0.004
Unknown Faucet Aerator	Aerators	37	0.002	0.004
Bathroom Faucet Aerator	Aerators	11	0.001	0.002
Kitchen Faucet Aerator	Aerators	64	0.003	0.006
Shower Head	Shower heads	63	0.003	0.007
Hot Water Temperature Setback	Water heaters receiving setback	82	0.009	0.009
Water Heater Blanket	Water heaters receiving blanket	79	0.009	0.009
Water Heater Pipe Wrap	Feet of insulation	22	0.003	0.003
Infiltration Reduction	Houses receiving infiltration measures	68	0.032	0.015
HVAC Filters	Houses receiving HVAC filters	49	0.015	0.011

Using the deemed savings values from Table 5-2 and the ISRs presented in Table 5-1, we calculated energy and demand savings for each measure in each program year. Table 5-3 shows the engineering analysis results for energy savings. The engineering analysis showed that the program saved 422 kWh per home in 2015 and 417 kWh per home in 2016, with a weighted average of 420 kWh across the two years. Differences in the mix of measures offered in 2015 and 2016 drove the variation in the average energy savings per household between two years. For example, in 2016, participants received on average one fewer CFL per home than in 2015 (see Table 6-2). Additionally, in 2015, the program offered 18 watt CFLs, which our engineering analysis estimated contributed two more kWh per year per CFL installed than the 20 watt CFLs offered in 2016. Finally, 2015 participants received water heater pipe wrap at a higher rate than 2016 participants: 38% in 2015 vs. 24% in 2016 (see Table 6-2). As pipe wrap is offered only to households with electric hot water heating, this difference has more to do with greater opportunities to install this measure in participating homes in 2015 than with any differences in implementation approach.

Table 5-3. Engineering Analysis Results: Energy Savings

Measure	Per-Unit Deemed Savings	GoodCents (2015)			Honeywell (2016)		
		ISR	Database Quantity	kWh	ISR	Database Quantity	kWh
9 Watt CFL	16.9	77%	0	0	87%	96	1,416
13 Watt CFL	25.4	77%	7,090	138,498	87%	9,192	203,416
18 Watt CFL	29.6	77%	5,706	130,040	87%	0	0
20 Watt CFL	28.0	77%	0	0	87%	1,289	31,378
Unknown Faucet Aerator	37.2	73%	2,156	58,570	78%	0	0
Bathroom Faucet Aerator	10.5	73%	0	0	78%	1,234	10,134
Kitchen Faucet Aerator	63.9	73%	0	0	78%	1,137	56,714
Shower Head	63.3	80%	924	46,580	85%	1,144	61,631
Hot Water Temperature Setback	81.6	100%	84	6,851	100%	76	6,197
Water Heater Pipe Wrap	14.9	100%	3,522	78,561	100%	2,485	55,430
Water Heater Blanket	78.6	100%	17	1,337	100%	151	11,874
Infiltration Reduction	68.4	97%	1,221	81,410	87%	1,276	76,187
HVAC Filters	48.6	78%	872	33,205	79%	902	34,652
Total Database Savings			—	**575,052**		—	**549,031**
Average Per Household			—	**422**		—	**417**

* Savings for all infiltration measures were calculated on a per-home basis.

Table 5-4 shows the demand savings for each program year for each measure. As with the energy savings, differences in the mix of measures between the two program years contributed to differences in the demand savings achieved in each year. The engineering analysis shows that the program saved on average 0.074 kW in 2015 and 0.071 kW in 2016 over the summer peak period per home, with a weighted average of 0.073 kW per home across the two years. Additionally over the winter peak period, the program saved 0.047 kW in 2015 and 0.048 kW in 2016 per home, with a weighted average of 0.048 kW per home across both years.

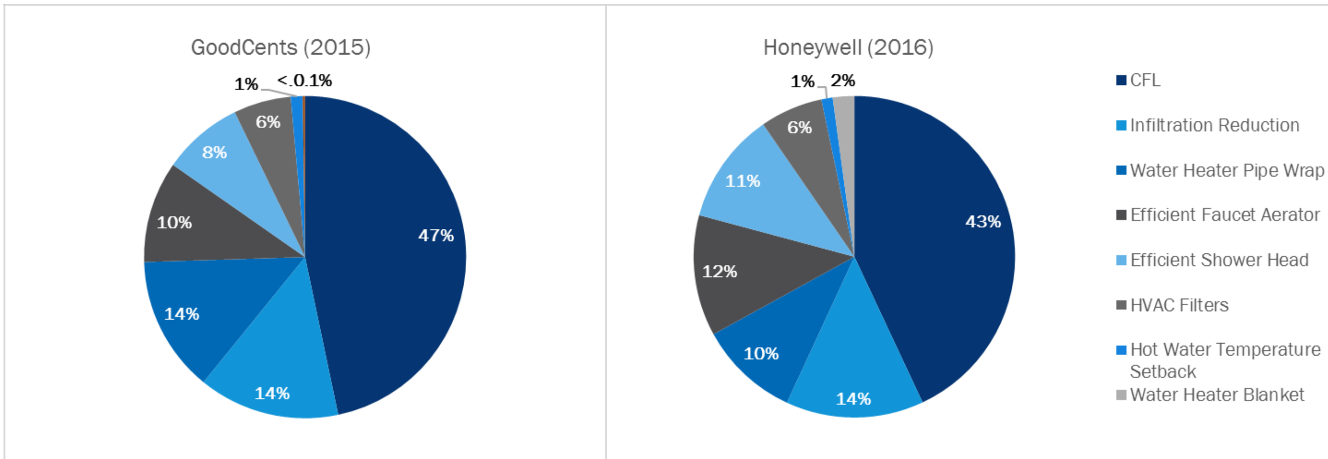
Table 5-4. Engineering Analysis Results: Demand Savings

Measure	Per-Unit Summer Peak Demand (kW)	Per-Unit Winter Peak Demand (kW)	GoodCents (2015)				Honeywell (2016)			
			ISR	Database Quantity	Summer kW	Winter kW	ISR	Database Quantity	Summer kW	Winter kW
9 Watt CFL	0.002	0.002	77%	0	0	0	87%	96	0.194	0.092
13 Watt CFL	0.003	0.003	77%	7,090	19.0	8.99	87%	9,192	27.9	13.2
18 Watt CFL	0.004	0.004	77%	5,706	17.8	8.44	87%	0	0	0
20 Watt CFL	0.004	0.004	77%	0	0	0	87%	1,289	4.30	2.04
Unknown Faucet Aerator	0.002	0.004	73%	2,156	3.32	6.64	78%	0	0	0
Bathroom Faucet Aerator	0.001	0.002	73%	0	0	0	78%	1,234	0.990	1.98
Kitchen Faucet Aerator	0.003	0.006	73%	0	0	0	78%	1,137	2.83	5.67
Shower Head	0.003	0.007	80%	924	2.55	5.09	85%	1,144	3.37	6.74
Hot Water Temperature Setback	0.009	0.009	100%	84	0.782	0.782	100%	76	0.707	0.707
Water Heater Pipe Wrap	0.003	0.003	100%	3,522	8.96	8.96	100%	2,485	6.32	6.32
Water Heater Blanket	0.009	0.009	100%	17	0.153	0.153	100%	151	1.35	1.35
Infiltration reduction*	0.032	0.015	97%	1,221	37.5	18.3	87%	1,276	35.1	17.1
HVAC Filters	0.015	0.011	78%	872	10.4	7.24	79%	902	10.9	7.56
Total Database Savings					**100**	**64.6**			**93.9**	**62.7**
Average Per Household					**0.074**	**0.047**			**0.071**	**0.048**

* Savings for all infiltration measures were calculated on a per-home basis.

Figure 5-2 shows the composition of energy savings by measure and year. In 2015, the largest share of energy savings came from lighting, followed by infiltration reduction, and hot water pipe wrap. Based on our engineering analysis, we estimated that these three measure groups combined contribute three-quarters of the total savings for the program year. As discussed previously in this section, both lighting and water heater pipe wrap accounted for a smaller share of energy savings in 2016 than in 2015. As such, the same three measure groups contributed approximately two-thirds of the program's energy savings in 2016. Though there were some minor fluctuations from year to year in the percentage that other measure groups contributed to the total energy savings, most remained relatively consistent.

Figure 5-2. Engineering Results: Percent of Total Energy Savings by Year



Based on the results of the engineering analysis, we calculated an overall kW per kWh savings ratio, as shown in Table 5-5. We applied this ratio to the billing analysis results to estimate net demand savings for both summer and winter peak periods.

Table 5-5. Engineering Demand-to-Energy Ratios

Metric	Summer Coincident Peak	Winter Coincident Peak
Average annual energy (kWh) savings per household*	420	420
Average demand (kW) per household	0.073	0.048
Ratio multiplier (kW/kWh)	0.0001729	0.0001132

* Opinion Dynamics calculated a weighted average of energy and demand savings per household for both program years to calculate the ratio multiplier.

5.3 Billing Analysis

5.3.1 Billing Analysis Methodology

Opinion Dynamics conducted a billing analysis to determine the overall evaluated net savings of the DEO NES program for 2015 and 2016. For this analysis, we used daily advanced metering infrastructure (AMI) billing data for all participants as of January 2013. To construct a comparison group, we gathered data for all customers in neighborhoods targeted in the 2017 program cycle. The use of a comparison group allows us to establish a counterfactual, i.e., the baseline energy that participants would have used in the absence of the program. In addition, because the comparison group represents energy use in the absence of the program, results from the billing analysis are net results, and the application of a net-to-gross ratio (NTGR) is unnecessary. This comparison group represents potential future participants, which carries the assumption that these customers possess many of the same attributes as the treatment group and have a similar propensity to participate in a low-income targeted energy efficiency program.

The billing analysis employed a LFER model, which accounts for factors that are not expected to vary before and after participation, such as square footage, appliance stock, habitual behaviors, household size, and other factors that do not vary over time. Such factors are represented in account-specific constant terms within the LFER model.

To improve our estimate of what baseline usage for participants would be absent the program, we added dummy variables for each calendar month, i.e., binomial terms with "1" signifying that the bill occurred in that month of the year. Including these variables in the model helped control for monthly trends that were unrelated to the comparison group and therefore resulted in a more accurate estimate of baseline usage absent the program. The model included weather terms and interaction terms between weather and the post-participation period for the treatment group, to account for differences in weather patterns across years. We also included a proxy for each account's normal rate of energy consumption prior to the program, in the form of its average daily energy consumption in 2014, to control for potential differences in the magnitude of energy used between participants in the two program years. The model results reflect savings associated with installed measures, participant spillover, and potential behavioral changes from energy efficiency knowledge gained during the assessment.

A large number of participants were not included in the model due to either insufficient data or participation in other DEO energy efficiency programs. Participation in other programs risks double counting energy savings and obscuring the effect of the NES program's influence on energy consumption. Since relatively few (27%) participants could be included in the final model, we conducted a comparative analysis of the customers included in the analysis ("modeled participants") and the total population of participants ("total participants"). We found that the modeled participants had very similar pre-participation period energy consumption to the rest of the 2015 and 2016 participants. Given this, we are comfortable with applying the modeled results to the total participant population. The breakdown of participants who were included in the final model is shown in Table 5-6.

Table 5-6. Total Participants vs. Modeled Participants

Year	Total Participants	Modeled Participants
2015	1,362	423
2016	1,314	297
Total 2015–2016	**2,676**	**720**

Due to the low quantity of participants from each program year that we were able to include in the model, we are unable to model the two years separately. A more detailed discussion of the billing analysis methodology, including data-cleaning steps, comparative statistics, and the final model, is provided in Appendix D.

5.3.2 Billing Analysis Results

This section presents the billing analysis results and savings estimates for the 2015–2016 program. Appendix D contains a detailed description of the methodology used for data cleaning and regression modeling, as well as complete results of the models. Table 5-7 summarizes the results of the billing model. The variable "Post (NES program participation)" represents the main effect of the treatment, i.e., the change in average daily consumption (ADC) attributable to participation in the NES program, controlling for weather and the magnitude of pre-participation program energy use.

Table 5-7. Results of Billing Analysis Model

Variable	Coefficient
Post (NES program participation)	1.646*
Cooling degree days (CDD)	3.695**
Heating degree days (HDD)	0.329***
Post-participation period CDD (interaction of Post x CDD)	−0.590***
Post-participation period HDD (interaction of Post x HDD)	0.0316
Average 2014 energy use	−0.133***
Constant	18.86***
Observations	3,159,813
R-squared	0.552

* p<0.1, ** p<0.05, *** p<0.01.

Due to post-participation period interaction terms in the model, the coefficient for the Post variable does not indicate the full program effect. To produce the full program effect, savings implied by the Post coefficient must be combined with additional savings that accrue with more extreme weather, as represented in the two interaction terms. The coefficients for the interaction terms were evaluated at the mean heating and cooling degree day values during the post-participation period. Specifically, the coefficients were multiplied by their respective degree days, and then added to the savings represented by the Post coefficient. The results of these adjustments are detailed in Appendix D. Opinion Dynamics found that 2015–2016 NES program participants realized an average 0.83 kWh of daily energy savings or 3.2% of their overall usage (see Table 5-8).

Table 5-8. Estimate of Daily Program Savings*

NES Estimate (ΔADC)	Standard Error	T	P>|t|	90% Confidence Interval	
				Lower	Upper
−0.83	0.253	−3.282	0.000	−1.2	−0.4

* Daily program savings estimate is the inverse of the coefficient for NES program participation in each respective model.

Table 5-9 shows the net per-home and program-level savings for the program and the participants. The estimate of percent savings is based on pre-participation period baseline usage of the full group of 2015 and 2016 participants. Overall, we found that DEO NES program participants, on average, saved 303 kWh per home in 2015–2016, i.e., 810,828 kWh for the program across the two years.

Table 5-9. Net Annual Savings from Billing Analysis

Year	Baseline Energy Consumption		Per Home Energy Savings			Participants	First-Year Program Savings (kWh)
	Daily (kWh)	Annual (kWh)	Daily (kWh)	Savings (%)	Annual (kWh)		
2015	25.7	9,381	0.83	3.2%	303	1,362	412,686
2016	25.7	9,381	0.83	3.2%	303	1,314	398,142
2015–2016	25.7	9,381	0.83	3.2%	303	2,676	810,828

5.4 Program Savings

The billing analysis results show that the NES program saved an average of 303 kWh per home annually for participants from 2015 and 2016. Table 5-10 compares the program's achieved savings to the savings assumptions presented in the prior 2013–2014 evaluation report. The last evaluation showed 412 kWh savings per home, producing a realization rate of 74%.

Table 5-10. Program Savings and Realization Rates

	Savings Assumptions*	2015–2016 Evaluated Net Savings	Realization Rate
Annual kWh (per participant)	412	303	74%
Annual summer kW (per participant)	0.128	0.052	41%
Annual winter kW (per participant)	0.137	0.034	25%

* Source: Process and Impact Evaluation of the 2013–2014 Residential Neighborhood Program in Ohio. Prepared for Duke Energy by TecMarket Works, February 2015.

The NES program design and implementation are very similar in the DEP, DEC, and DEI territories. In comparison to the program in those other Duke Energy territories, with the exception of DEI 2015, DEO had a lower annual baseline energy usage, although the energy savings as a percentage of baseline usage for the DEO service territory is fairly similar, as shown in Table 5-11.

Table 5-11. Percent and Per-Household Energy Savings in Comparable Duke Energy Programs

	DEP 2014	DEP 2015	DEC 2015	DEI 2015	DEO 2013–2014	DEO 2015–2016
Baseline energy use (annual kWh)	13,190	15,586	11,768	9,271	–	9,381
Percent savings of baseline energy use	2.6%	2.8%	2.9%	5.9%	–	3.2%
Average annual per-household energy savings (kWh)	367	430	347	548	412	303

* Source: Process and Impact Evaluation of the 2013–2014 Residential Neighborhood Program in Ohio. Prepared for Duke Energy by TecMarket Works, February 2015.

5.4.1 Program-Level Impacts for Regulatory Compliance

In the state of Ohio, electric distribution utilities (EDUs), including DEO, are required to achieve a cumulative annual energy savings of more than 22% by 2027 per Ohio Senate Bill (SB) 310. SB 310 also introduced new mechanisms that adjust how EDUs may estimate their energy savings achieved through demand side management programs. Specifically, SB 310 requires the Ohio Public Utilities Commission (PUCO) to permit EDUs to account for energy-efficiency savings estimated on an "as-found" or a deemed basis. That is, an EDU may claim savings based on the baseline operating conditions found at the location where the energy-efficiency measure was installed, or the EDU may claim a deemed savings estimate.

To support compliance with SB 310, Table 5-12**Error! Reference source not found.** below summarizes ex ante and ex post per household energy and demand savings. Per SB 310, DEO will claim 412 kWh of energy savings and 0.128 kW and 0.137 kW of peak summer and winter demand savings, respectively, per household for the 2015-2016 program years. These values are the higher of the ex ante and ex post savings values, based on the billing analyses conducted for the current and the previous evaluations.

Table 5-12. Per Household Savings for SB 310 Compliance

Unit of Measure	Ex Ante			Ex Post			Claimable under SB 310		
	kWh	kW Summer	kW Winter	kWh	kW Summer	kW Winter	kWh	kW Summer	kW Winter
Per home	412	0.128	0.137	303	0.052	0.034	412	0.128	0.137

6. Process Evaluation

6.1 Researchable Questions

Based on experience evaluating this program in other Duke Energy service territories and discussions with DEO program staff, Opinion Dynamics developed the following process-related research questions:

- What are the major strengths of the program? Are there specific ways that the program could be improved to be more effective in the future?
- Is the current measure mix appropriate, or are there additional measures that the program could add to increase the program's effectiveness and savings?
- What are the barriers to implementing this program, that is, are there limiting factors to achieving greater participation and realizing additional program-attributable savings?
- Is the educational component of the NES program effective and leading to persistent behavioral change?
- Would NES participants benefit from, or like, additional follow-up communication from the program after their participation? What communication methods would be effective?

6.2 Methods

Our process evaluation relied primarily on our interviews with program staff, our review of program materials and NES program-tracking data, and our analysis of the participant survey results. Each of these activities is described in more detail in Section 4.

6.3 Key Findings

6.3.1 Program Participation

The program years 2015 and 2016 were the third and fourth years of NES program implementation in Duke Energy's Ohio territory. During 2015 and 2016, the program served three neighborhoods: Madisonville (2015), Middletown (2015 and 2016), and Price Hill (2016). The program goal was to treat 1,339 households in each year of the program. The program served 1,362 unique households in 2015 (102% of goal) and 1,314 unique households in 2016 (98% of goal). In late 2015, the program implementer changed from GoodCents to Honeywell. In 2015, the program penetration rate, that is, the number of participants divided by the total number of eligible Duke customers in the targeted neighborhoods, was 30%; in 2016, this rate improved immensely, reaching approximately 72% of targeted DEO customers.

The difference in participation rates can be attributed largely to differences in the implementation approach of the two contractors. In 2015, GoodCents primarily used one-person installation crews and worked to generate appointments with customers in each neighborhood. During 2016, Honeywell took a canvassing approach and concentrated multi-person crews on each street in the targeted neighborhoods. Their teams focused their efforts on reaching the largest number of possible residents in each area, driving up the overall participation rate, which was a recently added goal for the program. The differences in approach resulted in higher penetration in 2016 than in 2015, as shown in Table 6-1.

Table 6-1. 2015 DEO NES Program Participation and Penetration

	2015	2016
Completed Projects	1,362	1,314
Penetration Rate	30%	72%

Most participants received all of the measure groups offered by the program. Table 6-2 shows the percent of homes that received at least one of each measure and the average quantity installed per home. The table also shows the percent of homes that received measures from each of four main categories: lighting, hot water, infiltration reduction, and educational/other. Across the two years, the measure mix remained relatively constant, with a few exceptions. As discussed in Section 5.2, though a similar percentage of homes received at least one CFL in both years, participants received, on average, one fewer CFL in 2016 than participants in 2015 did. Additionally, a higher share of 2016 participants received efficient faucet aerators and shower heads than in 2015, while a lower share of 2016 participants received water heater pipe wraps.

Table 6-2. Summary of 2015–2016 Measure Mix from Program-Tracking Data

Measure Category	Measure	GoodCents (2015)		Honeywell (2016)	
		Percent of Projects with At Least One Measure	Average Quantity Per Home	Percent of Projects with At Least One Measure	Average Quantity Per Home
Lighting	***Lighting Overall***	***95%***	***9***	***96%***	***8***
	9 Watt CFL	0%	0	4%	2
	13 Watt CFL	77%	7	94%	7
	18 Watt CFL	81%	5	0%	0
	20 Watt CFL	0%	0	35%	3
Hot Water	***Hot Water Overall***	***91%***	–	***99%***	–
	Efficient Faucet Aerator	86%	2	94%	2
	Efficient Shower Head	65%	1	83%	1
	Hot Water Temperature Setback	6%	1	6%	1
	Water Heater Pipe Wrap	38%	1	24%	1
	Water Heater Blanket	1%	1	11%	1
Infiltration Reduction	***Infiltration Reduction Overall***	***90%***	–	***98%***	–
	Caulking	43%	1	74%	1
	Door Sweep	68%	1	94%	1
	Foam Spray	11%	1	51%	1
	Poly Tape	2%	1	2%	1
	Weatherstripping	46%	1	68%	2
	Window Air Conditioner Cover	36%	2	55%	1
Educational/ Other	***Educational/Other Overall***	***97%***	–	***100%***	–
	HVAC Filters	64%	Package of 12	68%	Package of 12
	Wall Calendar	22%	1	0%	0
	Wall Thermometer	92%	1	93%	1

Cross-Participation

As part of the billing analysis, Opinion Dynamics also identified cross-participation of NES participants in other Duke Energy programs from January 2012 through October 2016. Table 6-3 below shows the breakdown of 2015 and 2016 NES participants for each of these programs. As illustrated below, the vast majority of NES participants who sign up for other programs do so for the Smart $aver program. These participants largely received lighting measures, while some received HVAC measures as well. Additionally, not surprisingly, cross participation is higher for 2015 NES participants as they have had more time to enroll in other Duke Energy programs than 2016 NES participants.

Table 6-3. Cross-Participation by Program Year

Program Name	GoodCents (2015)		Honeywell (2016)	
	Count of Participants	Percent of Total	Count of Participants	Percent of Total
Smart $aver	810	59%	431	33%
Weatherization Gas	46	3%	23	2%
Energy Maintenance Service	15	1%	1	0%
Appliance Recycle Program	8	1%	4	0%
Refrigerator Replacement	6	0%	3	0%
Residential EE Products & Services	5	0%	0	0%
Home Energy Solutions	4	0%	4	0%
Low Income Services	2	0%	4	0%
Residential Energy Assessments	2	0%	3	0%
Furnace Replacement Gas	1	0%	0	0%
Residential DR	1	0%	0	0%
Total Unique Cross-Participants	***852***	***63%***	***448***	***34%***
Total Participants	***1,362***	***–***	***1,314***	***–***

Note: Columns do not add up to total unique cross-participants as NES participants may have participated in multiple other Duke Energy programs.

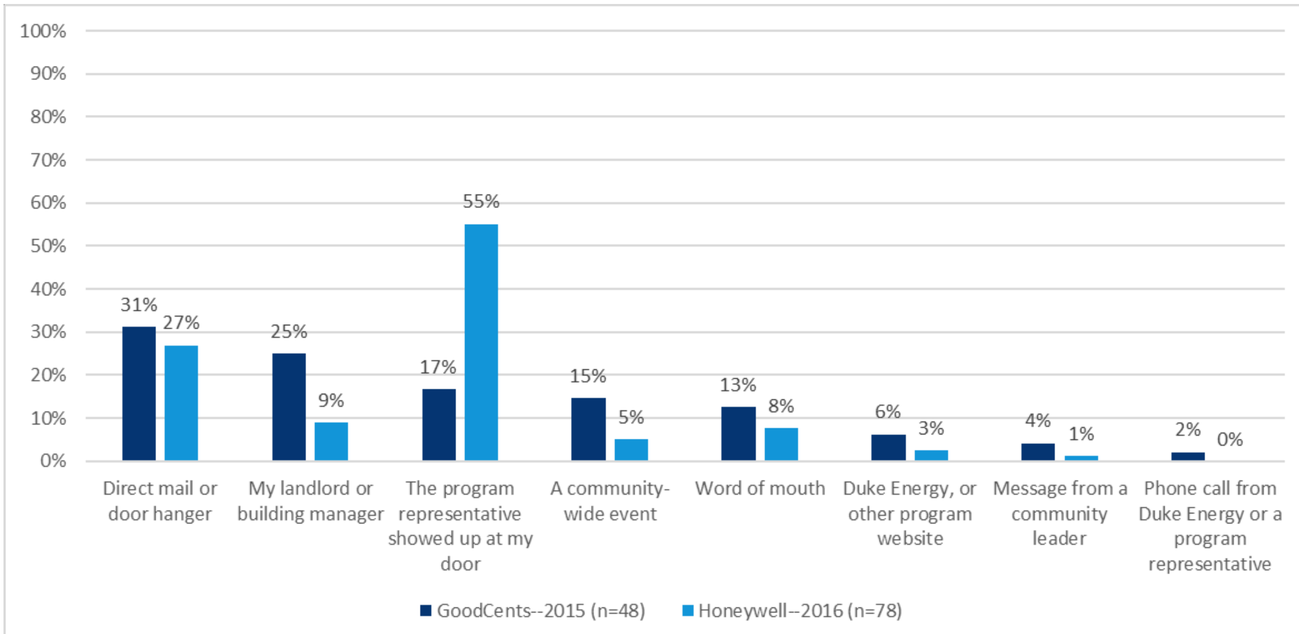
6.3.2 Marketing and Outreach

A key component of the NES program was the marketing and outreach that occurred at the outset of the program in each neighborhood. The program staff and implementation contractor performed this marketing and outreach to generate interest in the program specifically and in saving energy generally. With both vendors, the initial marketing approach remained the same. In 2015 and 2016, implementation teams sent an introductory letter and postcard to neighborhood residents two weeks prior to the neighborhood event, as well as ongoing marketing materials, such as door hangers, flyers, yard signs, and "last chance" mailings two weeks prior to the implementation crews leaving the neighborhood. Crews also went door-to-door to generate additional interest and awareness in the program. In 2016, the program used a similar set of marketing materials, but also included a postcard prior to the actual installation informing customers they would be on their street on a particular day.

Figure 6-1 shows participant responses about how they first heard about the NES program. In 2015, 31% of participants first heard about the program through direct mail or a door hanger, 25% heard about it through their landlord or a building manager, and 17% heard about the program when a program representative visited their home. In 2016, the most common way for participants to first hear about the program was a visit from the program representative at their home (55%), followed by receiving direct mail or a door hanger (27%).

The differences in how participants first heard about the program in 2015 and 2016 highlight the different implementation approaches between the two program implementers. As discussed in the previous section, Honeywell used an intensive neighborhood canvass approach along with mailings to generate awareness and interest, which is reflected in the participant survey responses shown in Figure 6-1.

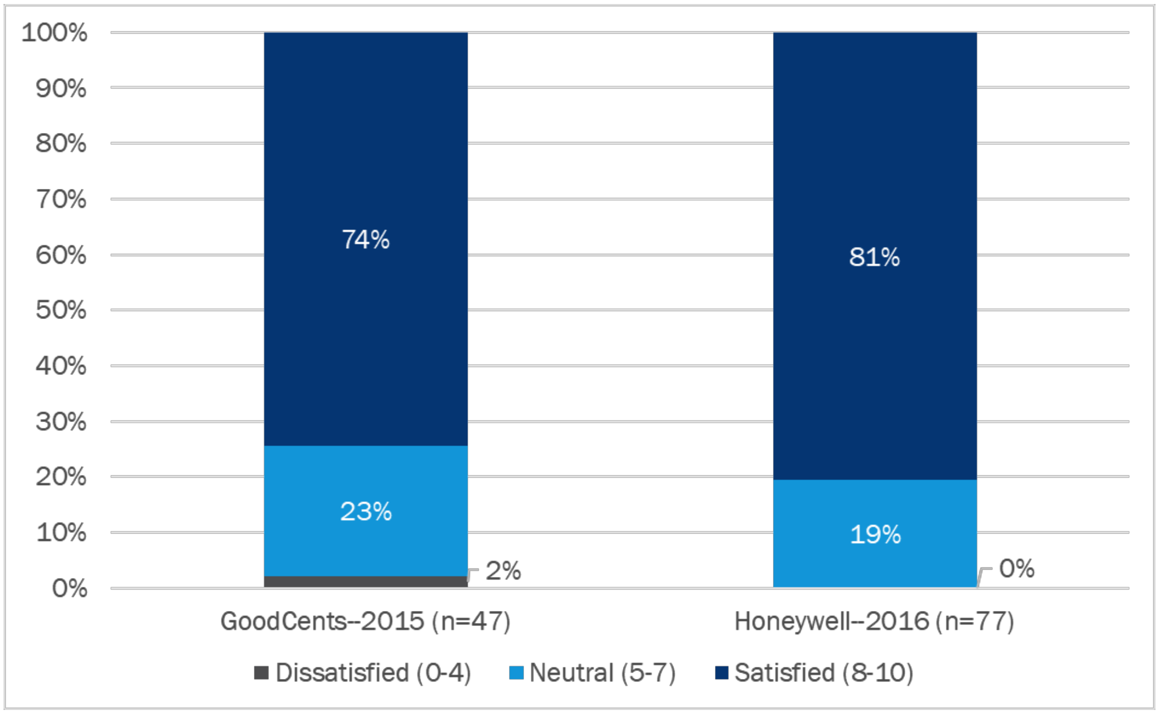
Figure 6-1. How Participants Heard About the Program (multiple responses)



6.3.3 Program Satisfaction

Program participants were satisfied with their experience with the NES program overall, as shown in Figure 6-2. Seventy-four percent of 2015 participants said that they were satisfied with the program; this level of satisfaction increased to 81% among 2016 participants. Only 2% of 2015 participants reported being dissatisfied with the program, while no 2016 participants said that they were dissatisfied.

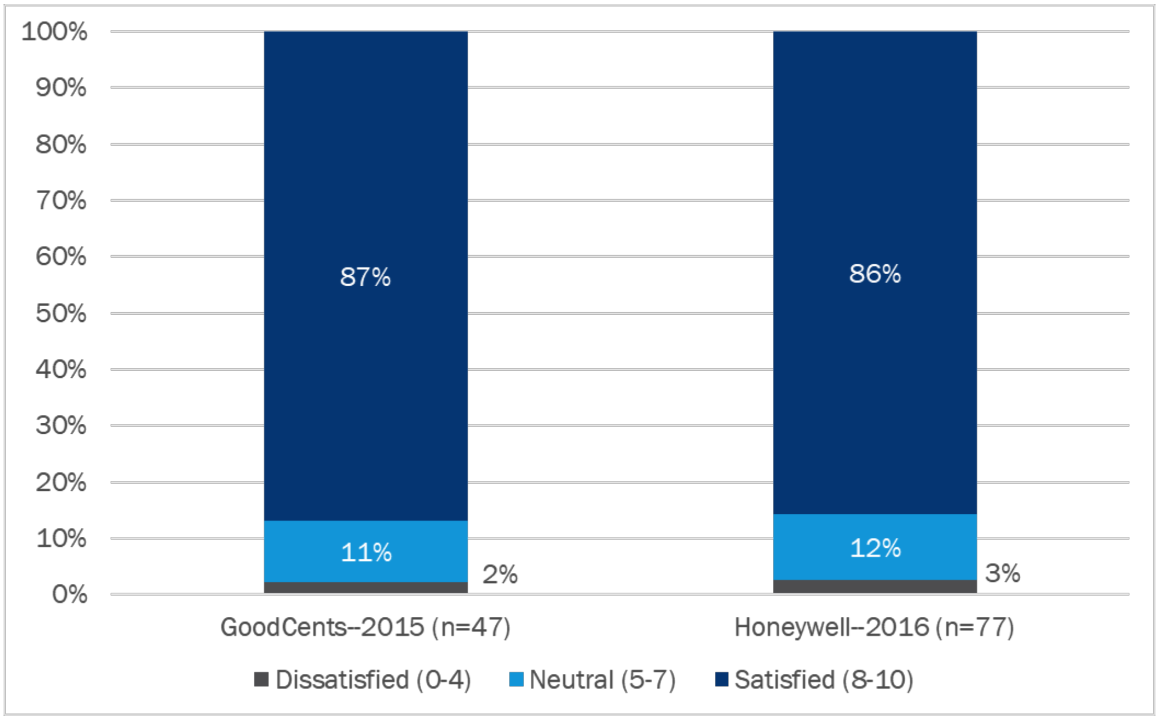
Figure 6-2. Satisfaction with the NES Program Overall



Note: Respondents were asked about their satisfaction with the program overall on a scale from 0 to 10, where 0 is "extremely dissatisfied" and 10 is "extremely satisfied."

Program participants were also highly satisfied with the NES program representative who visited their home (Figure 6-3). Eighty-seven percent of 2015 participants and 86% of 2016 participants said that they were satisfied with the program representative. Only 2% of 2015 participants and 3% of 2016 participants said that they were dissatisfied with the program representative.

Figure 6-3. Satisfaction with the NES Program Representative



Note: Respondents were asked about their satisfaction with the program staff that conducted their home visit on a scale from 0 to 10, where 0 is "extremely dissatisfied" and 10 is "extremely satisfied."

6.3.4 Energy Education

An important component of the NES program is the energy education that program staff provided to participants at the time of the home visits. Prior to participation, customers received some information about ways to save energy through mailings and flyers either left at their home or provided at the neighborhood launch event. Additionally, at the neighborhood launch event, program staff discussed the energy-saving measures that Duke Energy offers through the NES program and how each measure saves energy in participants' homes. During the program visit, participants received further explanation from a program representative about measures that the program provides and additional recommendations about other ways to save energy in their homes. Participants also received a brochure that reinforced the information provided by the program representative, along with other tips on energy-saving actions that they can take and other Duke programs that they can take advantage of.

During the participant survey, Opinion Dynamics asked program participants about the educational components of the program and how these components affected their behavior and attitudes toward saving energy after participation. Eighty-four percent of participants across both years said that they received in-person recommendations from program staff, and 67% of the participants who received recommendations found that information useful in helping them save energy. Also, 88% of participants in both years said that they received educational materials during their home visit, and, of those participants, 58% found the leave-behind materials useful in helping them save energy. When we break out both of these rates between the different program years, more participants reported receiving in-person recommendations and program leave-behind materials in 2016 (see Table 6-4). While this may be due in part to the inability of 2015 participants to recall the information that they received, we also believe that these increases are due to the differences in the contractors' implementation approach.

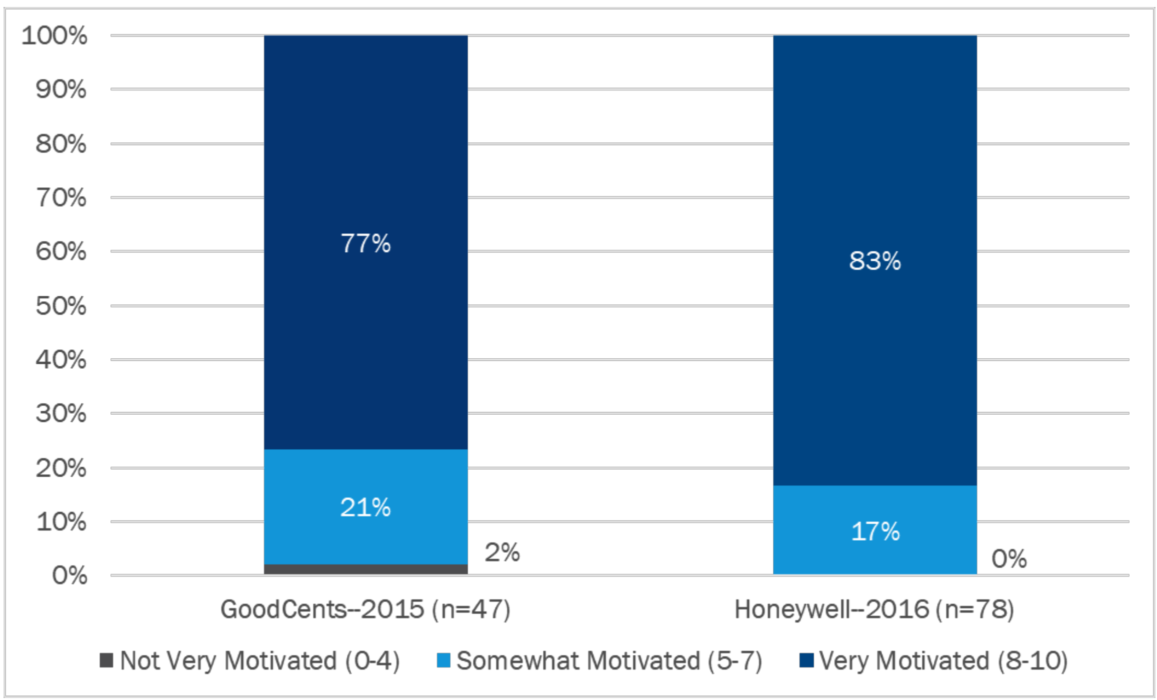
Table 6-4. Percent of Participants Receiving Educational Components

	GoodCents (2015) n=48	Honeywell (2016) n=78
In-Person Education	79%	90%
Program Leave-Behind Materials	81%	95%

During the participant survey, Opinion Dynamics also asked participants to rate their knowledge of ways to save energy before and after their participation in the NES program. Thirty-six percent of participants from both program years reported that they were knowledgeable about ways to save energy before participating in the NES program, while 73% reported the same level of knowledge after participating.

Further, 83% of 2016 program participants reported that they were motivated to reduce their energy use after participating in the NES program, while 77% of 2015 participants said the same. Only 2% of 2015 participants and no 2016 participants said that they were not very motivated to save energy at all after participating in the NES program.

Figure 6-4. Motivation to Reduce Energy Use after NES Program Participation

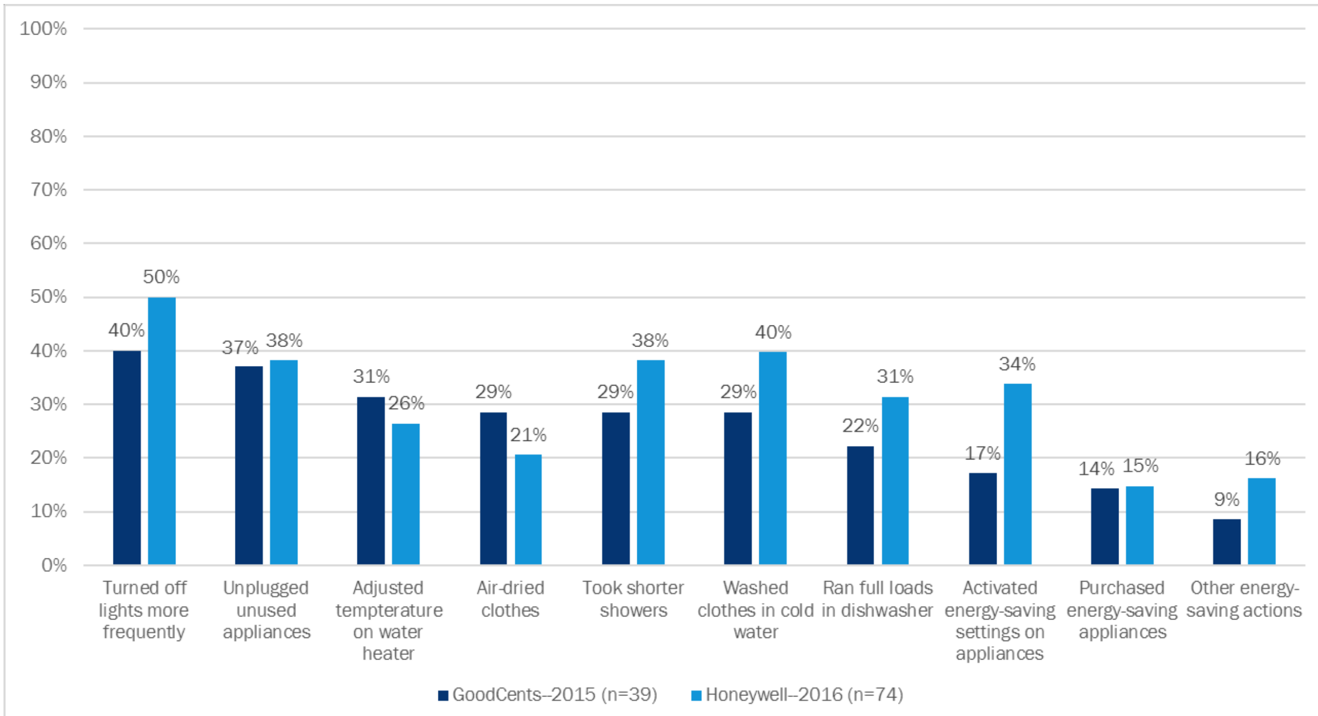


Note: Respondents were asked about their motivation to reduce their household's energy use on a scale from 0 to 10, where 0 is "not motivated at all" and 10 is "extremely motivated."

To determine if the educational component of the NES program resulted in actual energy-saving behavioral changes, we also asked the 88% of participants who reported receiving educational leave-behind materials about energy-saving actions that they have taken since participating in the NES program. Figure 6-5 shows the actions participants from each program year reported taking since participating. Participants from both program years reported taking high levels of energy-saving actions. However, in general, 2016 participants reported taking action more frequently (74, 95%) than did 2015 (39, 83%) participants. Once again, these differences may be due in part to the inability of 2015 participants to recall the actions that they had taken since participating in the program.

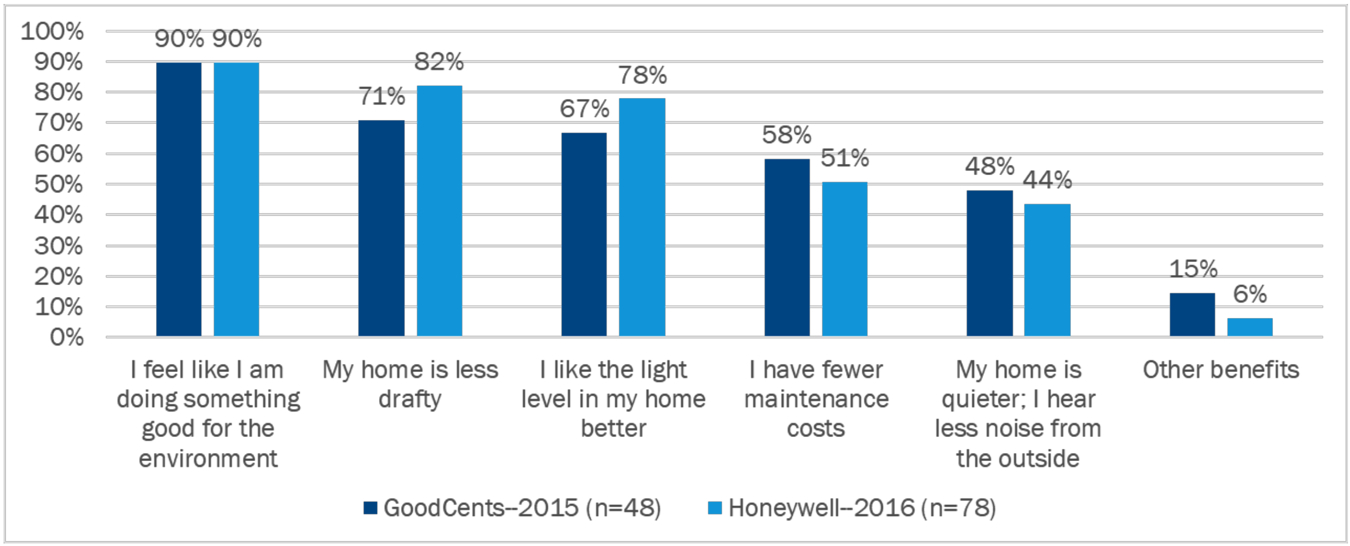
Among 2016 participants, the most frequent energy-saving actions were turning off lights more frequently (50%), washing clothes in cold water (40%), taking shorter showers (38%), and unplugging unused appliances (38%). Among 2015 participants, 40% turned lights off more frequently, 37% unplugged unused appliances, and 31% adjusted the temperature on their water heater.

Figure 6-5. Energy-Saving Actions Taken (multiple responses)



During the participant survey, we also asked participants about other benefits that they may have experienced after participating in the program. Nearly half (48%) of participants from both program years noticed a change in their electric bill after participating in the NES program. Of those who saw a change in their electric bill, 82% said that their bill went down. We also prompted participants with a list of other benefits that they may have noticed since participating in the program (see Figure 6-6). Ninety percent of participants in each year said that they felt that they were doing something good for the environment. Seventy-one percent of 2015 participants and 82% of 2016 participants reported that their home was less drafty. Sixty-seven percent of 2015 participants and 78% of 2016 participants said that they like the light level in their home better. Smaller percentages of participants also reported that they had fewer maintenance costs and that their home was quieter.

Figure 6-6. Other Program Benefits Experienced by Participants (multiple responses)



6.3.5 Additional Opportunities for Program Savings

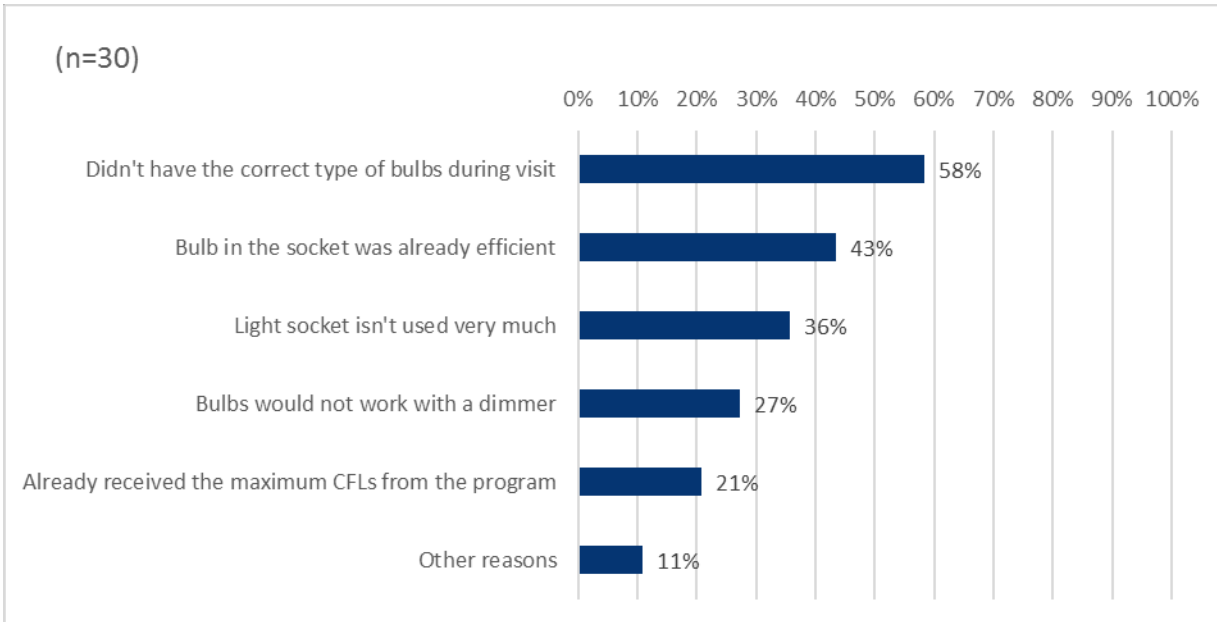
One objective of the process evaluation was to determine if there are opportunities for increasing program savings with additional types of measures. For example, some income-qualified programs provide energy-efficient replacements of older, inefficient appliances. To identify potential opportunities, Opinion Dynamics asked participants about their existing lighting and appliances during the participant survey. Specifically, we asked respondents about any light bulbs that were not replaced during the visit, as well as about the presence and age of refrigerators, dehumidifiers, and air conditioning systems.

Lighting

With the rapid efficiency improvements in the standard lighting market that resulted from the 2007 Energy Independence and Security Act (EISA) and various lighting-related technological advances, the opportunities for direct-install programs to install high-efficiency bulbs in standard high-use sockets are becoming increasingly scarce. Existing standard lighting is more efficient, reducing baseline energy use and associated energy savings from efficiency upgrades. However, specialty lighting may still be a source of additional savings opportunities for the NES program, which currently does not offer specialty lighting measures.

To identify additional applications for lighting measures, Opinion Dynamics asked NES program participants about bulbs in their homes that were not replaced by the program representative. Twenty-four percent of participants reported that, on average, eight bulbs were not replaced during the visit. Of those participants, fifty-eight percent said that the program representative didn't have the correct type of light bulbs at the time of the visit, while 43% said that they already had an efficient bulb in place. Thirty-six percent said that the light socket was not used very much, and 27% said that the available bulbs would not work with a dimmer switch (see Figure 6-7).

Figure 6-7. Reasons Bulbs Were Not Replaced (multiple responses)



As a result of previous evaluations of this program in other Duke Energy jurisdictions, the increasing efficiency of existing standard lighting and price reductions in LED lamps, the NES program will begin offering LEDs in place of CFLs in future program years.

Refrigerators

Older model refrigerators, frequently found in lower-income homes, can account for a substantial portion of annual household energy use. To characterize the prevalence of older, inefficient refrigerators among the NES program participants, we asked participants to estimate the age of their refrigerator. The most recent U.S. Department of Energy (DOE) efficiency standards for refrigerators went into effect in September 2014; prior standards were in effect from July 2001 to September 2014.[7]

NES program participants from both years reported that their refrigerators were on average almost 7 years old, and only 5% of participants reported that their refrigerators were manufactured before the change in DOE efficiency standards in 2001. More information on the existing equipment would be necessary, including metered energy usage from a representative sample of refrigerators, to estimate the potential savings from refrigerator replacements among the DEO NES participant population.

Window Air Conditioners

To determine if there is potential for the NES program to offer efficient window air conditioner replacements, we asked participants if they had window air conditioners and, if so, to estimate their ages. Eighty-six percent of participants reported having air conditioning in their home. Of those participants, 45% had central air conditioners; 37% had window units; and 4% had other types of air conditioning, such as portable units or heat pumps.

[7] See U.S. Department of Energy Standards for Refrigerators at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=37&action=viewlive.

Among those who had window air conditioners, on average, participants had about two units, 4.3 years old. The most recent DOE room air conditioner standards went into effect in June 2014, when energy efficiency ratio (EER) levels increased for room air conditioners.[8] Prior to this most recent federal standard, a standard was in place from October 1, 2000 to May 31, 2014.[9] As such, Opinion Dynamics does not recommend adding window air conditioner replacements to the NES program at this time.

Dehumidifiers

Older and inefficient dehumidifiers are also the target of some income-qualified programs. Replacing these dehumidifiers with new ENERGY STAR® units can save approximately 260–360 kWh per year.[10] Opinion Dynamics asked NES program participants if they had a dehumidifier and, if so, to estimate its age. Twenty-four percent of participants reported having a dehumidifier in their home, and the average age of these dehumidifiers was 6.8 years. The most recent DOE dehumidifier standards went into effect for products manufactured in or after October 2012. The prior standard was in place from October 2007 to October 2012.[11] More research and data collection would be needed to determine the extent of this measure as a savings opportunity for the NES program.

Participant Suggestions for Program Improvement

We also asked participants for suggestions on what improvements or changes they would like to see in the program design. Almost one-third of participants interviewed (n=40) made suggestions for improvements, including:

- Offering additional insulation or air sealing measures (n=7)
- Spending more time on education or training (n=5)
- Offering different lighting options, such as LED or specialty bulbs (n=4)
- More-efficient appointment scheduling (n=3)
- More follow-up appointments (n=2)

[8] U.S. Department of Energy standards for room air conditioners apply to window air conditioners and those designed to be mounted through a wall.

[9] See U.S. Department of Energy Standards for Window Air Conditioners at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52&action=viewlive.

[10] Opinion Dynamics calculation based on inputs from IL TRM Version 4.0, Mid-Atlantic TRM Version 4.0, and Pennsylvania TRM.

[11] See U.S. Department of Energy Standards for Dehumidifiers at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=24&action=viewcurrent.

7. Conclusions and Recommendations

The following sections outline our conclusions and recommendations from the DEO NES impact and process evaluation for 2015 and 2016. We outline several of the program's key strengths and potential barriers to gaining increased participation and savings.

7.1 Conclusions

7.1.1 Program Strengths

Program Participant and Penetration Rate

The NES program achieved strong participation during both 2015 and 2016. In 2015, DEO program administration staff exceeded their participation goal, reaching 1,362 DEO customers. In 2016, the program served 1,314 participants, falling within the allowable 10% deviation relative to its participation goal and exceeded its neighborhood penetration goal. The 2015 participants accounted for approximately 30% of the DEO customers in the targeted neighborhoods, compared with over 70% in 2016. Though the lower penetration rate in 2015 was partially due to external factors, it was driven largely by the implementation approach in 2015. Beginning in 2016, similar to other Duke Energy service territories that offer the NES program, program administration staff introduced a new goal of reaching at least 70% of eligible customers targeted through the DEO NES program. They surpassed this goal in 2016, achieving a penetration rate of approximately 72%. As this program provides an opportunity for DEO to provide free measures and energy education that are of great benefit to NES participants, offering program benefits to the highest possible percentage of DEO customers in a given neighborhood helps expand the customer reach.

Educational Component

One of the greatest strengths of the DEO NES program is the high level of energy education offered to participants, which, in part, drives the consistently high levels of participant satisfaction. Eighty-four percent of participants received in-person recommendations from program staff and 88% of participants received educational leave-behind materials. Additionally, the majority of those participants found the recommendations and leave-behind materials useful in helping them save energy in their home.

Program Data Tracking

The DEO NES program team has incorporated data-tracking recommendations from previous evaluations of the NES program in other Duke Energy service territories. In 2016, program implementation staff began to track housing characteristics, such as the presence of central air conditioning systems, the type of heating system, and the water heating fuel type. Additionally, program staff tracked certain appliance characteristics, such as refrigerator make and model, boiler tank size, and whether or not the household has window air conditioning units. Tracking these types of data while program staff are on-site is the most accurate way of characterizing NES program participants and will assist with program planning and evaluation moving forward.

7.1.2 Program Barriers

Per-Home Savings

Based on the billing analysis, the DEO NES program achieved savings of 303 kWh per household on average during the 2015 and 2016 program years, which translates to 3.2% of participants' average yearly energy consumption. With the exception of DEI, this rate is consistent with other NES participants, who save close to 3% of their average yearly consumption. However, given the lower-than-average baseline energy consumption compared to other Duke Energy service territories, we expect lower absolute per-participant savings as there is lower potential energy savings available for customers who consume less energy.

Measure Mix

Based on the housing characteristics of NES participants in the Cincinnati area, there may be limited opportunity to realize higher levels of savings per-household with the current mix of measures offered by the NES program. Table 7-1 compares savings and other key attributes of NES participants across the different Duke Energy service territories that offer the NES program. The purpose of the table below is to compare the average energy consumption, the mix of fuel-types, and differences in equipment penetration across the different service territories. Note that we have included the impact values below based on reported values from previous program evaluations and we do not control for the variations in climate zones and customer bases across the different Duke Energy service territories. This comparison reveals key differences in the DEO territory, including lower rates of central air conditioning, electric space heating, and electric water heating, which may contribute to lower annual energy savings per household. Additionally, with the exception of DEI, territories with higher average baseline energy consumption experienced higher annual energy savings.

Table 7-1. Comparison of Recently Evaluated Duke Energy NES Programs

Territory and Year	Implementer	Annual kWh Savings per Home	Average Baseline Consumption per home (kWh/yr.)	Savings as a Percent of Baseline Usage	Percent Single Family	Percent Central AC	Number of CFLs	Percent Electric Heat	Percent Electric Hot Water
DEO 2015-16	GoodCents / Honeywell	303	9,286	3.2%	63%	45%	9	20%	28%
DEO 2013-14*	GoodCents	412	------	------	74%	59%	11	23%	40%
DEI 2015	Honeywell	548	9,271	5.9%	48%	84%	12	32%	40%
DEC 2015	GoodCents	347	11,768	2.9%	74%	64%	7	49%	69%
DEP 2015	Honeywell	430	15,584	2.8%	72%	66%	8	61%	81%
DEP 2014	Honeywell	367	13,190	2.6%	80%	50%	8	49%	72%

* Source: Process and Impact Evaluation of the 2013–2014 Residential Neighborhood Program in Ohio. Prepared for Duke Energy by TecMarket Works, February 2015.

7.2 Recommendations

Below we provide our recommendations for potential program improvements. These recommendations are based on the results of the participant survey, the billing analysis, the engineering analysis, interviews with program staff, and our experience evaluating similar income-qualified programs.

- **Offer specialty lighting.** In addition to offering LEDs, which NES participants began receiving in 2017, the program should assess opportunities for specialty lighting products. Savings opportunities from replacing bulbs in lower-use sockets are limited given that these sockets tend to have lower hours of use. However, there may be opportunities to replace specialty bulbs with more-efficient options. Specifically, 24% of 2015 and 2016 participants did not have some bulbs replaced with CFLs during the visit. Of these participants, fifty-eight percent attributed this to the program representative not having the correct bulb during their home visit, and 27% said that the program CFL would not have worked with a dimmer switch.
- **Investigate potential savings and costs of additional measures frequently offered through income-qualified programs.** From 2015 to 2016, the portion of the program's energy savings coming from CFL replacements fell from 47% to 43% respectively. As savings opportunities from efficient lighting measures continue to decrease, additional program offerings would allow the program to maintain consistent levels of energy savings per-household. The program should consider the feasibility of adding other measures commonly offered by income-qualified programs, such as advanced power strips and programmable thermostats, to diversify and increase program savings.
- **Investigate the feasibility of refining neighborhood targeting.** When compared to NES participants in other Duke Energy service territories, DEO NES participants from 2015 and 2016 have the lowest average baseline energy consumption. While DEO NES participants save a similar savings percentage, their overall average savings is lower. The types of households and housing stock in the 2015 and 2016 participant population may be responsible for their lower overall energy savings. Our research suggests that these participants had lower central air conditioner, electric heat, and electric water heater penetration than neighborhoods targeted in other Duke Energy service territories.

  DEO program staff currently leverage MapPoint software to identify neighborhoods with eligible customers based on income levels. We recommend for consideration, if feasible, augmenting targeting efforts by incorporating average energy consumption within the neighborhood, in addition to the income threshold used to determine neighborhood eligibility. This will allow program staff to continue to reach a broad range of DEO customers, while also helping to maximizing potential energy savings from NES participants.
- **Continue to leverage a canvassing approach to support high penetration rates**. From 2013 through 2015, NES program implementers had goals for the total number of customers served through the program each year. Beginning in 2016, Duke Energy set an additional goal to achieve 70% penetration in each neighborhood selected. To address this additional goal, Honeywell staff canvassed each street within the selected neighborhoods, performing assessments and installations when customers were available and leaving behind their contact information via door hangers when they were not. This canvassing approach achieved a much higher penetration rate than GoodCents' appointment-driven approach.
- **Continue to focus on energy education**. According to the participant survey, the program's energy education component increases participant knowledge about energy savings practices and likely contributes to energy savings. Survey respondents reported completing a suite of energy savings behaviors promoted by the program. Program staff should continue to promote this aspect of the program.
- **Track water heater temperature setbacks.** The two program implementers tracked water heater temperature setbacks differently in 2015 and 2016. Specifically, in 2015, the measure was labeled "Water Heater Temperature Adjustment," while for 2016, it was labeled "Water Heater Temperature Check," but did not track hot water tank temperature set point adjustments. We recommend explicitly tracking when the program representatives makes these adjustments moving forward.

8. Summary Form

Neighborhood Energy Saver

Completed EMV Fact Sheet

The Neighborhood Energy Saver (NES) program provides a home energy assessment free of cost, and installs energy-saving measures in the homes of income-qualified customers living in DEO service territory. During the assessment, program representatives discuss what was installed and provide additional recommendations on ways participants can save energy in their homes.

Date	November 17th, 2017
Region(s)	Duke Energy Ohio
Evaluation Period	January 1, 2015 – December 31, 2016
Claimed Savings Per SB 310	
Annual kWh	1,102,512
Per Participant kWh	412
Per Participant Coincident kW	0.128 (Summer) 0.137 (Winter)
Savings From Billing Analysis	
Annual kWh	810,828
Per Participant Net kWh	303
Per Participant Coincident Net kW	0.052 (Summer) 0.034 (Winter)
Measure Life	Not evaluated, remains unchanged at 7 years
Net-to-Gross Ratio	1.0 (Deemed)
Process Evaluation	Yes
Previous Evaluation(s)	Yes, 2013–2014 Evaluation

Evaluation Methodology

Opinion Dynamics verified deemed savings estimates using an engineering analysis of savings assumptions and calculations. We also leveraged a participant survey to verify installation and ISRs for each measure and characterized behavior change resulting from the program's educational component. In addition, Opinion Dynamics conducted a billing analysis to estimate energy savings and a combination of billing analysis results and engineering analysis to estimate peak demand savings.

Impact Evaluation Details

- Neighborhoods in DEO service territory where at least 50% of residential customers are at or below 200% of the federal poverty guidelines are eligible to participate in the NES program.
- The engineering analysis applied deemed savings values to measures distributed and in service. ISRs were calculated based on information gleaned from a participant survey. To comply with SB 310, claimed savings will consist of estimates of gross impacts based on the larger of the ex ante and ex post savings.
- Results from the billing analysis reflect savings associated with measures installed, assessment recommendations, spillover, and potential behavioral changes from energy efficiency knowledge gained through participation in the NES program.

9. DSMore Table

The Excel spreadsheet embedded below contains participant-level savings inputs for Duke Energy Analytics.

DSMore table -
DEO Low Income Ne

Appendix A. Survey Instruments and Detailed Survey Results

- Participant Survey Instrument

Duke
Energy_Participant S

- Detailed Survey Results

7880-Duke
Energy-DEO 2015-LI

Appendix B. Impact Calculation Tables

Duke Energy_Deemed Sav

Appendix C. Engineering Algorithms and Assumptions Overview of Deemed Savings Review

Per the evaluation plan for the 2015–2016 DEO NES program, Opinion Dynamics conducted a review of the deemed savings values and assumptions of the NES measures. The primary source for 2015–2016 evaluated program savings is the billing analysis, but the deemed savings review is used to estimate demand savings from the billing analysis results and to provide estimates of savings at the measure level. The following sections describe the methodology for estimating savings from each measure in more detail.

To conduct our deemed savings review, Opinion Dynamics first reviewed inputs and algorithms (as available) from the 2013–2014 EM&V report.[12] We then performed an engineering analysis using various TRMs and secondary sources to develop per-unit savings estimates for the NES measures. We prioritized the use of the IN and OH TRMs whenever possible, as the inputs and assumptions are typically more applicable to DEO territory. We also updated assumptions based on the results of the participant survey.

CFLs

Table C-1 documents the inputs and methodology for estimating savings for CFLs for the NES program in 2015 and 2016.

Table C-1. Algorithms and Inputs for CFLs

Algorithms Used		
kWh Savings	= (Baseline Watts – CFL Watts) / 1,000 * Hours * (1 + WHFe)	
kW Savings (summer)	= (Baseline Watts – CFL Watts) / 1,000 * CF_s * (1 + $WHFd_s$)	
kW Savings (winter)	= (Baseline Watts – CFL Watts) / 1,000 * CF_w * (1 + $WHFd_w$)	
Parameter	**Value**	**Source/Notes**
Baseline Watts	Varies	From ENERGY STAR website, converts CFL wattage to equivalent incandescent wattage and then adjusts based on EISA requirements. See Table C-2.
CFL Watts	Varies	Actual wattage of installed bulb (9, 13, 14, 19, 20, or 23 watts).
Hours	902	IN TRM V2.2.
WHFe	−0.061	IN TRM V2.2, Indianapolis. Used the IN TRM as it relies on data that are more recent, and we assume Indianapolis as it is the closest city to DEO territory.
Summer Demand Waste Heat Factor ($WHFd_s$)	0.055	
Winter Demand Waste Heat Factor ($WHFd_w$)	−0.500	2012 DEP Energy Efficient Lighting Program Evaluation.
Summer Coincidence Factor (CF_s)	0.11	IN TRM V2.2 for summer CF. Consistent with OH TRM (2010) assumption. Assume same CF for winter CF due to lack of available data for winter CF in the Midwest.
Winter Coincidence Factor (CF_w)	0.11	

[12] Process and Impact Evaluation of the 2013–2014 Residential Neighborhood Program in Ohio. Prepared for Duke Energy by TecMarket Works, February 2015.

Table C-2 displays a crosswalk between installed CFL wattage and assumed baseline incandescent wattage taken from the ENERGY STAR website. We then adjust the incandescent wattages to account for EISA requirements[13] and use the reduced EISA baseline in our engineering estimates.

Table C-2. ENERGY STAR Equivalent Incandescent Wattages

CFL Wattage	Equivalent Incandescent Wattage[a]	EISA Baseline (watts)
9 to 13 watts	40	29
13 to 15 watts	60	43
18 to 25 watts	75	53
23 to 30 watts	100	72

[a] http://goo.gl/XjRoUk.

Table C-3 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. The 2013–2014 EM&V report does not provide individual savings estimates for the different types of CFLs; therefore, we assumed the energy and demand savings from the 2013–2014 EM&V report are average values across all CFLs.

Table C-3. Per-Measure Savings for CFLs

Measure (per bulb)	Savings Unit	2015–2016	2013–2014 EM&V Report
9 Watt CFLs	Energy Savings (kWh)	16.9	34.4 kWh 0.0039 kW
	Summer Demand Savings (kW)	0.0023	
	Winter Demand Savings (kW)	0.0011	
13 Watt CFLs	Energy Savings (kWh)	25.4	
	Summer Demand Savings (kW)	0.0035	
	Winter Demand Savings (kW)	0.0017	
18 Watt CFLs	Energy Savings (kWh)	29.6	
	Summer Demand Savings (kW)	0.0041	
	Winter Demand Savings (kW)	0.0019	
20 Watt CFLs	Energy Savings (kWh)	28.0	
	Summer Demand Savings (kW)	0.0038	
	Winter Demand Savings (kW)	0.0018	
23 Watt CFLs	Energy Savings (kWh)	41.5	
	Summer Demand Savings (kW)	0.0057	
	Winter Demand Savings (kW)	0.0027	

CFL Recommendations

Our methodology generally agrees with the methodology used during previous evaluations. Moving forward, the program should consider collecting the wattage of the removed bulbs to provide a more accurate energy savings estimate. Alternatively, to minimize time spent in each home, these data could be collected from a

[13] EISA set in place standards for general service light bulbs, with the first phase going into effect in January 2012. The standard essentially eliminates the manufacture and sale of 40W, 60W, 75W, and 100W incandescent light bulbs and sets new standards as shown in the table.

representative sample of participants in each neighborhood and the results applied to the remaining participant population.

LEDs

While the NES program does not presently offer LEDs, Duke Energy has expressed interest in adding these measures in the future. This section provides deemed savings methods and estimates for LEDs as background information to help inform a decision on whether to include LEDs as a program measure.

The following section documents the expected savings from LEDs, assuming an incandescent baseline and identical hours of use and coincidence factors used in the CFL savings calculations.[14] Table C-4 documents the inputs and methodology for estimating savings for LEDs.

Table C-4. Algorithms and Inputs for LEDs

<table>
<tr><th colspan="3">Algorithms Used</th></tr>
<tr><td>kWh Savings</td><td colspan="2">= (Baseline Watts – LED Watts) / 1,000 * Hours * (1 + WHFe)</td></tr>
<tr><td>kW Savings (summer)</td><td colspan="2">= (Baseline Watts – CFL Watts) / 1,000 * CF_s * (1 + $WHFd_s$)</td></tr>
<tr><td>kW Savings (winter)</td><td colspan="2">= (Baseline Watts – CFL Watts) / 1,000 * CF_w * (1 + $WHFd_w$)</td></tr>
<tr><th>Parameter</th><th>Value</th><th>Source/Notes</th></tr>
<tr><td>Baseline Watts</td><td>Varies</td><td>Varies according to installed LED wattage. See Table C-5.</td></tr>
<tr><td>LED Watts</td><td>Varies</td><td>Actual wattage of installed bulb.</td></tr>
<tr><td>Hours</td><td>902</td><td>IN TRM V2.2.</td></tr>
<tr><td>WHFe</td><td>−0.061</td><td rowspan="2">IN TRM V2.2, Indianapolis. Used the IN TRM as it relies on data that are more recent, and we assume Indianapolis as it is the closest city to DEO territory.</td></tr>
<tr><td>Summer Demand Waste Heat Factor ($WHFd_s$)</td><td>0.055</td></tr>
<tr><td>Winter Demand Waste Heat Factor ($WHFd_w$)</td><td>-0.500</td><td>2012 DEP Energy Efficient Lighting Program Evaluation.</td></tr>
<tr><td>Summer Coincidence Factor (CF_s)</td><td>0.11</td><td rowspan="2">IN TRM V2.2 for summer CF. Consistent with OH TRM (2010) assumption. Assume same CF for winter CF due to lack of available data for winter CF in the Midwest.</td></tr>
<tr><td>Winter Coincidence Factor (CF_w)</td><td>0.11</td></tr>
</table>

Table C-5 displays a crosswalk of wattages between incandescent bulbs and the equivalent CFLs and LEDs.[15] Most resources provide a range of equivalent wattages for CFLs and LEDs since exact wattage comparisons with incandescent bulbs can be imprecise. We adjust the incandescent wattages to account for EISA requirements and use the reduced EISA baseline in our engineering estimates.

Table C-5. Equivalent CFL and LED Wattages

Incandescent (baseline) Watts	CFL Watts	LED Watts	Lumens (Brightness)
40	8–12	6–9	400–500
60	13–18	8–12.5	650–900

[14] While there is reason to believe that hours of use and coincidence factors for LEDs may be different from CFLs, there currently are no LED-specific values that we recommend using. We will update these assumptions with LED-specific information, based on the forthcoming residential light logging study for the DEC Residential Lighting Program.

[15] http://eartheasy.com/live_energyeff_lighting.htm.

Incandescent (baseline) Watts	CFL Watts	LED Watts	Lumens (Brightness)
75–100	18–22	13+	1,100–1,750
100	23–30	16–20	1,800+
150	30–55	25–28	2,780

To estimate savings from installing LED bulbs, we assume an equivalent LED wattage based on the CFL wattages currently installed through the program. Table C-6 provides this comparison between CFLs and LEDs in the first column. Table C-6 also displays the deemed savings for LEDs, compared with the deemed savings of equivalent CFLs currently installed through the program.

Table C-6. Per-Measure Savings for LEDs

Measure (per bulb)	Savings Unit	CFL Savings	LED Savings
9 Watt CFLs (7 Watt LEDs)	Energy Savings (kWh)	16.9	18.6
	Summer Demand Savings (kW)	0.0023	0.0026
	Winter Demand Savings (kW)	0.0011	0.0012
13 Watt CFLs (8 Watt LEDs)	Energy Savings (kWh)	25.4	29.6
	Summer Demand Savings (kW)	0.0035	0.0041
	Winter Demand Savings (kW)	0.0017	0.0019
18 Watt CFLs (14 Watt LEDs)	Energy Savings (kWh)	29.6	33.0
	Summer Demand Savings (kW)	0.0041	0.0045
	Winter Demand Savings (kW)	0.0019	0.0021
20 Watt CFLs (15 Watt LEDs)	Energy Savings (kWh)	28.0	48.3
	Summer Demand Savings (kW)	0.0038	0.0066
	Winter Demand Savings (kW)	0.0018	0.0031
23 Watt CFLs (16 Watt LEDs)	Energy Savings (kWh)	41.5	47.4
	Summer Demand Savings (kW)	0.0057	0.0065
	Winter Demand Savings (kW)	0.0027	0.0031

Efficient Shower Heads

Table C-7 documents the inputs and methodology for estimating efficient shower head savings for the 2015–2016 NES program.

Table C-7. Algorithms and Inputs for Efficient Shower Heads

Algorithms Used		
kWh Savings	= (Baseline Gallon per Minute [GPM] − Efficient GPM) * (Mins/shower) * (Showers/person) * (People/household) / (Shower fixtures/household) * 365 * (Tmix − Tinlet) * 8.33 / 3,412 / RE * %Elec	
kW Savings	= (Baseline GPM − Efficient GPM) * 60 * 8.33 * (Tmix − Tinlet) / RE / 3,412 * CF * %Elec	
Parameter	**Value**	**Source/Notes**
Baseline GPM	2.63	IN TRM V2.2.
Efficient GPM	1.74	IN TRM V2.2.
Mins/shower	7.8	Michigan Evaluation Working Group Showerhead and Faucet Aerator Meter Study. June 2013 (Michigan Showerhead/Faucet Aerator Study).
Showers/person	0.6	Michigan Showerhead/Faucet Aerator Study.
People/household	2.41	2016 Participant Survey (n=119).
Shower fixtures/ household	1.63	IN TRM V2.2.
Tmix	101°F	Michigan Showerhead/Faucet Aerator Study.
Tinlet	60.2°F	National Renewable Energy Laboratory (NREL) Domestic Hot Water Event Generator calculator for Cincinnati.
RE	0.98	Recovery efficiency for standard electric resistance water heaters (consistent assumption across IL TRM, IN TRM, OH TRM, Arkansas [ARK] TRM). Tennessee Valley Authority TRM applies the overall efficiency of the water heater (0.89) as opposed to the recovery efficiency.
%Elec	27.7%	2016 Participant Survey (n=112).
Summer CF	0.0023	IN TRM V2.2. Consistent with OH TRM (2010) assumption.
Winter CF	0.0046	According to Duke, the winter peak in Ohio is from 7PM to 8 PM. Reliable data do not exist for winter CFs for showers during the 7PM–8PM hour. We expect customers to use showers more frequently during the winter peak hour than during the summer peak hour (4PM–5PM). We assume the frequency is approximately double, and therefore double the summer CF to estimate winter CF.

Table C-8 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. Our methodology generally agrees with the methodology used during previous evaluations, except for the people/household and shower fixtures/household parameters, which the 2013–2014 EM&V report excluded. For other parameters, we cannot confirm the reference for assumptions in the 2013–2014 EM&V report, such as temperatures, shower head flow rates, shower duration, number of showers per day, and CFs. We chose to use assumptions that we can reference clearly from recent studies in Ohio or nearby jurisdictions, which leads to the discrepancy in deemed savings across evaluations.

Table C-8. Per-Measure Savings Comparison for Efficient Shower Heads

<table>
<tr><th>Measure
(per shower head)</th><th>Savings Unit</th><th>2015–2016</th><th>2013–2014 EM&V Report</th></tr>
<tr><td rowspan="3">Efficient Shower Head</td><td>Energy Savings (kWh)</td><td>63.3</td><td>139.6</td></tr>
<tr><td>Summer Demand Savings (kW)</td><td>0.0035</td><td rowspan="2">0.0103</td></tr>
<tr><td>Winter Demand Savings (kW)</td><td>0.0069</td></tr>
</table>

Efficient Shower Head Recommendations and Useful Data

If feasible, the DEO NES program should consider documenting the new shower head flow rate (in GPM) and, if possible, the flow rate of the removed shower head to more accurately estimate how efficient showerheads contribute to savings per household. Alternatively, to minimize time spent in each home, these data could be collected from a representative sample of participants in each neighborhood and the results applied to the remaining participants.

Efficient Faucet Aerators

Table C-9 documents the inputs and methodology for estimating aerator savings for the 2015–2016 NES program. We estimate savings for bathroom faucet aerators and kitchen faucet aerators separately, as the two measures perform differently in their use. For example, households tend to use kitchen faucets more than bathroom faucets throughout the day and they typically have a higher flow rate.

Table C-9. Algorithms and Inputs for Faucet Aerators

Algorithms Used		
kWh Savings	= (Baseline GPM – Efficient GPM) * (Minutes/person/day) * (People/household) / (Faucets/household) * 365 * (Tmix – Tinlet) * 8.33 / 3,412 / RE * DF * %Elec	
kW Savings	= (Baseline GPM – Efficient GPM) * 60 * 8.3 * (Tmix – Tinlet) / RE / 3,412 * CF * DF * %Elec	
Parameter	**Value**	**Source/Notes**
Baseline GPM (bathroom)	1.9	IN TRM V2.2. OH TRM (2010) does not distinguish between bathroom and kitchen faucet aerators.
Baseline GPM (kitchen)	2.44	
Efficient GPM (bathroom)	1.01	IN TRM V2.2. OH TRM (2010) does not distinguish between bathroom and kitchen faucet aerators.
Efficient GPM (kitchen)	1.49	
Minutes/person/day (bathroom)	1.6	IN TRM V2.2. Michigan Showerhead/Faucet Aerator Study.
Minutes/person/day (kitchen)	4.5	
People/household	2.41	2016 Participant Survey (n=119).
Faucets/household (bathroom)	1.91	IN TRM V2.2. OH TRM (2010) does not distinguish between bathroom and kitchen faucet aerators.
Faucets/household (kitchen)	1.0	
Tmix (bathroom)	86°F	IN TRM V2.2. Michigan Showerhead/Faucet Aerator Study
Tmix (kitchen)	93°F	
Tinlet	60.2°F	NREL Domestic Hot Water Event Generator calculator for Cincinnati.
RE	0.98	Recovery efficiency for standard electric resistance water heaters (consistent assumption across IL TRM, IN TRM, OH TRM, ARK TRM). TVA TRM applies the overall efficiency of the water heater (0.89) as opposed to the recovery efficiency.
%Elec	27.7%	2016 Participant Survey (n=112).
Summer CF	0.0023	IN TRM V2.2. OH TRM (2010) assumption is unsourced.
Winter CF	0.0046	According to Duke, the winter peak in Ohio is from 7PM to 8PM. Reliable data do not exist for winter CFs for showers during the 7PM–8PM hour. We expect customers to use showers more frequently during the winter peak hour than during the summer peak hour (4PM–5PM). We assume the frequency is approximately double, and therefore double the summer CF to estimate winter CF.
Drain Factor (DF) (bathroom)	90%	IL TRM. This represents the portion of the water that actually flows directly down the drain and not collected for another purpose. If the water is collected, it will not save any energy, as the volume is constant regardless of the flow rate. We use the IL TRM assumption, as we believe it is more realistic than the IN TRM V2.2 assumption. OH TRM (2010) does not distinguish between bathroom and kitchen faucet aerators.
DF (kitchen)	75%	

Table C-10 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. We distinguish between bathroom and kitchen faucet aerators, but also calculate a weighted average based on data from another direct-install income-qualified program that found approximately a 50/50 split of bathroom and kitchen faucet aerators installed.

We generally agree with the algorithm used in the 2013–2014 EM&V report, but that report does not provide clear references to the different assumptions, such as faucet aerator flow rates, people per home, and faucets per home, among others. We chose to use assumptions that we can reference clearly from recent studies in Ohio or nearby jurisdictions, which leads to the discrepancy in deemed savings across evaluations.

Table C-10. Per-Measure Savings Comparison for Faucet Aerators

Measure (per aerator)	Savings Unit	2015–2016	2013–2014 EM&V Report
Faucet Aerator (bathroom)	Energy Savings (kWh)	10.5	10.8 kWh 0.0013 kW
	Summer Demand Savings (kW)	0.0010	
	Winter Demand Savings (kW)	0.0021	
Faucet Aerator (kitchen)	Energy Savings (kWh)	63.9	
	Summer Demand Savings (kW)	0.0032	
	Winter Demand Savings (kW)	0.0064	
Weighted Average	Energy Savings (kWh)	37.2	
	Summer Demand Savings (kW)	0.0021	
	Winter Demand Savings (kW)	0.0042	

Faucet Aerator Recommendations and Useful Data

If feasible, the program should consider measuring and documenting the new faucet aerator flow rate (in GPM) and, if possible, the flow rate of the faucet before installing the new aerator to more accurately estimate the contribution of faucet aerators to savings per household. Alternatively, to minimize time spent in each home, these measurements could be taken from a representative sample of participants in each neighborhood and the results applied to the remaining participant population.

Infiltration Reductions

Table C-11 documents the inputs and methodology for estimating infiltration reduction savings for the 2015–2016 NES program. This measure includes savings for all infiltration reduction measures associated with the NES program, including door sweeps, caulk, foam spray, glass patch tape, weatherstripping, and winterization kits.

Table C-11. Algorithms and Inputs for Infiltration Reductions

Algorithms Used		
kWh Savings	Cooling Savings = (CFM50Exist − CFM50New) / Nfactor * 60 * 24 * CDD * DUA * 0.018 / 1,000 / nCool * AF * LM * %AC Heating Savings = (CFM50Exist − CFM50New) / Nfactor * 60 * 24 * HDD * 0.018 / 3,412 / nHeat * AF * %electric heat	
kW Savings (summer)	Cooling kWh Savings / FLHcool * CF	
kW Savings (winter)	Heating kWh Savings / FLHheat	
Parameter	**Value**	**Source/Notes**
Baseline ACH50	17.4	

Upgrade ACH50	17.0	ENERGY STAR savings analysis assumptions for Cincinnati (Climate Zone 4). https://energycode.pnl.gov/EnergyCodeReqs/. Assume air sealing for "Windows, Doors and Walls." https://www.energystar.gov/ia/home_improvement/home_sealing/Measure_Upgrade_Assumptions.pdf?945a-eddc.
Home volume (ft^3)	13,889	Conditioned square footage from 2016 Participant Survey is 1,736 square feet (n=41). Assume ceiling height of 8 feet.
Baseline CFM50	4,028	Converts ACH50 to CFM50 (= ACH50 * Volume / 60 minutes). http://www.pureenergyaudits.com/docs/Blower_Door_Handout_ACI_Baltimore.pdf.
Upgrade CFM50	3,935	
N-factor	16.27	IN TRM V2.2. Average of all values. OH TRM (2010) uses maximum value rather than average.
Conversion	1,440	Converts ft^3/min to ft^3/day.
CDD	1,155	ASHRAE Fundamentals 2013, Cincinnati.
Discretionary use adjustment (DUA)	0.75	Common to most TRMs.
Heat capacity	0.018	Volumetric heat capacity of air.
Efficiency of air conditioning (nCool)	13	Assume 13 SEER based on several TRMs. Assume equipment installed after 2006.
Latent multiplier (LM)	8.3	Latent multiplier to account for latent cooling demand. This is used to convert the sensible cooling savings to a value representing both sensible and latent cooling loads. The value is derived from Harriman et al., "Dehumidification and Cooling Loads from Ventilation Air," ASHRAE Journal, November 1997. We used Dayton, OH, as the city to represent DEO territory. We calculate the multiplier by adding the latent (2.9) and sensible (0.4) and dividing by the sensible.
%AC	44.0%	2016 Participant Survey (n=125).
Cooling kWh Savings	35.7	Calculated.
HDD	4,744	ASHRAE Fundamentals 2013, Cincinnati.
nHeat	1.2	Calculated. Weighted average based on type of heating in Ohio from Residential Energy Consumption Survey (RECS) data.
% electric heat	19.5%	2016 Participant Survey (n=118).
% heat pump	18%	U.S. Energy Information Administration, 2009 RECS, Ohio.
% resistance	82%	
COP heat pump	2.26	IN TRM V2.2.
COP electric resistance	1.0	
Heating kWh Savings	32.7	Calculated.
FLHcool	996	U.S. Environmental Protection Agency (EPA) (2002) for Cincinnati.
Summer CF	0.88	IN TRM V2.2. Duke Energy data for residential air conditioning loads.
Winter CF	1.0	Review of several TRMs. Assume heating operates during peak winter hour.
FLHheat	2,134	EPA (2002) for Cincinnati.

Table C-12. displays the deemed savings for the 2015–2016 evaluation. We group all infiltration reduction measures together to calculate savings, as they all relate to air sealing and calculating savings for the individual measures can be imprecise. The 2013–2014 EM&V report provides savings by measure, but references DOE-2 simulations in addition to ASHRAE calculations, and it is not clear how the previous evaluation team used these two methods to determine the final deemed savings.

Due to the significant differences in methods used to quantify and report savings between the method described above and that used in the 2013–2014 EM&V report, providing a comparison is not feasible[16]. Therefore, we only present our 2015--2016 deemed savings in Table C-12.

Table C-12. Per-Measure Savings for Infiltration Reductions

Measure	Savings Units	2015–2016
Infiltration Reductions (per home)	Energy Savings (kWh)	68.4
	Summer Demand Savings (kW)	0.0315
	Winter Demand Savings (kW)	0.0153

HVAC Filters

Table C-13 documents the inputs and methodology for estimating HVAC filter savings for the 2015–2016 NES program. We based savings on RECS 2009 data and a study performed by Lawrence Berkeley National Laboratory (LBNL) that measures the effects of HVAC filters in homes.[17] The LBNL study states that regularly[18] replacing air filters reduces the energy consumption for HVAC equipment by 1%. We applied the 1% reduction to the average annual energy consumption for several types of HVAC equipment to arrive at average annual filter energy savings per home.

Table C-13. Algorithms and Inputs for HVAC Filters

Algorithms Used		
kWh Savings	= Annual kWh consumption * % savings	
kW Savings (summer)	= Cooling kWh * % savings * Summer CF / FLHcooling	
kW Savings (winter)	= Heating kWh * % savings * Winter CF / FLHheating	
Parameter	**Value**	**Source/Notes**
Annual kWh consumption	4,856	RECS 2009 data.
% savings	1%	LBNL study.
Cooling kWh	3,013	RECS 2009 data.
Heating kWh	1,843	
Summer CF	0.88	IN TRM V2.2. Duke Energy data for residential air conditioning loads.
Winter CF	1.0	Review of several TRMs. Assume heating operates during peak winter hour.
FLHcooling	996	EPA (2002) for Cincinnati.
FLHheating	2,134	

Table C-14 displays the deemed savings values for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. The 2013–2014 EM&V report based savings on a Southern California Edison Company work paper for efficiency reductions due to dirty filters and building simulations for annual fan energy use. Our methodology uses the LBNL study for estimating the percent reduction in energy savings due to changing filters regularly and RECS data for average HVAC energy consumption.

[16] The 2013–2014 EM&V report provides savings broken out by measure (weatherstripping, caulking, door sweep, foam insulation), which are all in different units of measure (linear foot, per door, etc.). For this reason, comparing its deemed savings to our household-level savings estimate is not accurate.

[17] LBNL. "System Effects of High Efficiency Filters in Homes." March 2013. http://eetd.lbl.gov/sites/all/files/lbnl-6144e.pdf.

[18] Air filters should be replaced monthly or bimonthly (depending on frequency of use and the levels of dust or contaminants within the home) according to DOE. http://energy.gov/energysaver/articles/maintaining-your-air-conditioner.

Table C-14. Per-Measure Savings for HVAC Filters

Measure	Savings Unit	2015–2016	2013–2014 EM&V Report
HVAC Filters	Energy Savings (kWh)	48.6	35.63
	Summer Demand Savings (kW)	0.027	0.0015
	Winter Demand Savings (kW)	0.009	

Water Heater Pipe Wraps

Table C-15 documents the inputs and methodology for estimating water heater pipe wrap savings for the 2015–2016 NES program.

Table C-15. Algorithms and Inputs for Water Heater Pipe Wrap

Algorithms Used		
kWh Savings	= (1 / Rexist − 1 / Rnew) * L * C * ΔT * 8,766 / nDHW / 3,412	
kW Savings	= kWh saved / 8,766	
Parameter	**Value**	**Source/Notes**
R-value of existing pipe (Rexist)	1	IL TRM. Assumed R-value of existing pipe. Navigant Consulting Inc., April 2009, "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," p. 77.
R-value of pipe and insulation (Rnew)	3	IN TRM V2.2. ASHRAE Fundamentals Chapter 23 - Table 2: 1. For a fluid design operating temperature range of 105–140°F, the insulation conductivity is 0.22–0.28 Btu * in/h * ft^2 * °F. Assume midpoint (0.25). 2. To determine R-value, we divide the thickness of the insulation by the insulation conductivity (R-value = insulation thickness [inches] / thermal conductivity [Btu * in/h * ft^2 * °F]). 3. Assume 0.5 inch insulation based on standard pipe insulation thickness. 4. R-value = 0.5 inch thickness / 0.25 Btu * in/h * ft^2 * °F = R-2. 5. This R-value is added to the existing (R-1) to get the total new R-value (R-3).
Length (L) in feet	1	Assume 1 foot length and multiply by total length for each project.
Circumference (C) in feet	0.196	Assume 0.75 inch diameter pipe. For 0.75 inch diameter pipe, circumference is 0.196 feet (C = 3.14 * 0.75 / 12).
Temperature difference (ΔT)	65°F	IN TRM V2.2. Consistent with OH TRM (2010) assumption.
Recovery efficiency of electric hot water heater (nDHW)	0.98	IN TRM V2.2. Consistent with OH TRM (2010) assumption.
CF	1.0	Savings are realized 8,766 hours/year and through the full peak hours. There is no difference between summer and winter peak CFs.

Table C-16 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. Our algorithm is consistent with the algorithm used in the 2013–2014 EM&V report. Slight differences exist between the R-value of the insulation that is added and the circumference of the pipe. All other inputs are identical between the two methods. Since the 2013–2014 EM&V report does not clearly source all inputs, we chose to use our own values taken from ASHRAE. The 2015–2016 deemed savings is per foot of insulation and should be multiplied by the total length of pipe to accurately estimate savings.

Table C-16. Per-Measure Savings Comparison for Water Heater Pipe Wraps

Measure (per foot of pipe wrap)	Savings Unit	2015–2016	2013–2014 EM&V Report
Water Heater Pipe Wrap	Energy Savings (kWh)	22.3	26.70
	Summer Demand Savings (kW)	0.0025	0.0031
	Winter Demand Savings (kW)	0.0025	

Hot Water Temperature Setbacks

Table C-17 documents the inputs and methodology for estimating hot water temperature setback savings for the 2015–2016 NES evaluation. The OH TRM and the IN TRM do not include an algorithm for hot water temperature setbacks so we use the IL TRM methodology.

Table C-17. Algorithms and Inputs for Hot Water Temperature Setbacks

Algorithms Used		
kWh Savings	= (U * A * (Tpre – Tpost) * Hours) / (3,412 * RE_electric)	
kW Savings	= kWh saved / 8,766 * CF	
Parameter	**Value**	**Source/Notes**
U-value of tank (U)	0.083	IL TRM. Assumes R-12 or U-0.083.
Surface area of tank (A)	24.99	IL TRM. Varies based on tank size. Currently assumes 50-gallon tank.
Tpre (°F)	135	According to PY2013 (DEP) Appendix B, 135°F was the lower-bound threshold for hot water temperature setbacks. Assume this also applies to DEO.
Tpost (°F)	120	Target temperature after setbacks, according to PY2013 (DEP) EM&V report. Assume this also applies to DEO.
Hours	8,766	Hours in a year that the savings occur, assumed to be constant over the year (IL TRM).
RE_electric	0.98	IN TRM V2.2. Consistent with OH TRM (2010) assumption.
CF	1	Savings are realized 8,766 hours/year and through the full peak hours. There is no difference between summer and winter peak CFs.
Conversion factor	3,412	Conversion factor from BTUs to kWh

Table C-18 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. The previous evaluation applied the methodology and savings assumptions provided by the New York TRM. We cannot confirm the reference for assumptions in the 2013–2014 EM&V report, such as heat transfer coefficients and temperatures. We therefore used a method from the IL TRM that is common for hot water temperature setbacks and consistent across multiple TRMs.

Table C-18. Per-Measure Savings Comparison for Hot Water Temperature Setbacks

Measure (per water heater)	Savings Unit	2015–2016	2013–2014 EM&V Report
Hot Water Temperature Setback	Energy Savings (kWh)	81.6	81.63
	Summer Demand Savings (kW)	0.0093	0.0093
	Winter Demand Savings (kW)	0.0093	

Hot Water Temperature Setback Recommendations and Useful Data

We recommend collecting the size of the hot water tanks if feasible and the pre- and post-temperature setbacks to more accurately estimate savings moving forward. Alternatively, to minimize time spent in each home, these measurements could be taken from a random sample of participants in each neighborhood and the results applied to the remaining participant population.

Water Heater Blankets

Table C-19 documents the inputs and methodology for estimating water heater blanket savings for the 2015–2016 NES program evaluation.

Table C-19. Algorithms and Inputs for Water Heater Blankets

Algorithms Used		
kWh Savings	= (kWhbase * Efnew – Efbase / Efnew)	
kW Savings	= kWh saved / 8,766 * CF	
Parameter	**Value**	**Source/Notes**
kWhbase	3,460	IN TRM V2.2 (electric water heater).
Efnew	0.88	IN TRM V2.2.
Efbase	0.86	IN TRM V2.2.
Hours/year	8,766	IN TRM V2.2.
CF	1	Savings are realized 8,766 hours/year and through the full peak hours.

Table C-20 displays the deemed savings for the 2015–2016 evaluation, compared with the deemed values from the 2013–2014 EM&V report. The previous evaluation used the same methodology that we use for the 2015–2016 evaluation. However, slight differences exist in assumed R-values and surface area of the tank. The 2013–2014 EM&V report does not provide references for the assumptions used. We therefore used assumptions from the IN TRM.

Table C-20. Per-Measure Savings Comparison for Water Heater Blankets

Measure (per water heater)	Savings Unit	2015–2016	2013–2014 EM&V Report
Water Heater Blanket	Energy Savings (kWh)	78.6	136.2
	Summer Demand Savings (kW)	0.009	0.0156
	Winter Demand Savings (kW)	0.009	

Water Heater Blanket Recommendations and Useful Data

If feasible, we recommend collecting the size of the water heater tanks if possible and the R-value of the insulation installed through this measure to more accurately estimate how water heater blankets contribute to per-household savings. Alternatively, to minimize time spent in each home, these measurements could be taken from a random sample of participants in each neighborhood and the results applied to the remaining participant population.

Key References

Table C-21 provides several of the key references used in developing deemed savings for each of the measures included in the DEO NES program.

Table C-21. Key References

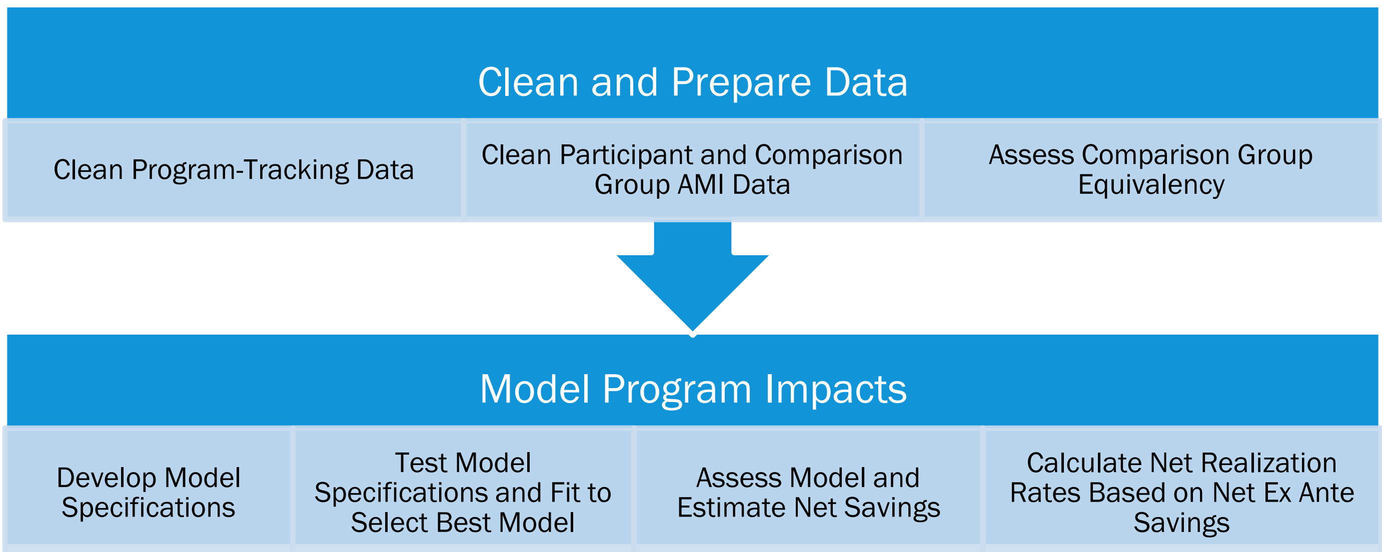
Reference	Source
EPA 2002	ENERGY STAR Calculator for Air Source Heat Pumps.
IL TRM	Illinois Technical Reference Manual. Version 4.0. February 24, 2015.
IN TRM	Indiana Technical Reference Manual. Version 2.2. July 28, 2015.
Michigan Showerhead/Faucet Aerator Study	Michigan Evaluation Working Group Showerhead and Faucet Aerator Meter Study Memorandum. June 2013.
Mid-Atlantic TRM	Mid-Atlantic Technical Reference Manual. Version 4.0. June 2014.
OH TRM	Ohio Technical Reference Manual. August, 6, 2010.
RECS Data	U.S. Energy Information Administration, 2009 Residential Energy Consumption Survey (RECS), Ohio.

Appendix D. Detailed Methodology: Billing Analysis

Opinion Dynamics conducted a billing analysis using a LFER model, with the goal of determining the overall ex post net program savings of the DEO NES program. The model allows all household factors that do not vary over time to be absorbed (and therefore controlled for) by the individual constant terms in the equation. Specifically, this method uses home-specific intercepts.

As part of the billing analysis of NES program participants, we followed a standard series of steps for data collection, model specification, and analysis. Figure D-1 provides a summary of our billing analysis approach.

Figure D-1. Billing Analysis Approach



Clean and Prepare Data

This section summarizes how we cleaned and prepared the 2015 and 2016 program participant databases and AMI data for the billing analysis.

Clean Program-Tracking Data

As a first step in preparing the necessary data, Opinion Dynamics prepared a master participant dataset that combined the program-tracking data, from each year of the NES program, with dates of participation in other Duke Energy energy efficiency programs. This master dataset is composed of customer information that includes:

- **Participation date:** The date of participation determines the program for each account, and differentiates pre- and post-participation periods in our model.
- **Participation in other programs:** Customers who participated in multiple energy efficiency programs during the time period were identified and excluded, as they would likely skew the observed effect of the NES, or double count savings from other programs, if they are not accounted for or removed.
- **Location:** We used the address and zip code of each customer to incorporate regional weather data.

Clean Participant and Comparison Group AMI Data

We used AMI billing data to conduct the billing analysis. These data were provided by DEO at a daily level, from January 2013 to April 2017. To develop the final dataset used for statistical analysis, we used a multi-step approach to combining and cleaning the data. We describe each billing data-cleaning step below.

- **Clean individual billing periods**:
  - **Check for consistency in dates and read times in each observation:** We found that most records showed 24 hours between start and end time stamps. Observations with 23 or 25 hours corresponded with changes in daylight savings time, and were not cause for concern. A small number of records were dropped because they represented a partial day.
  - **Remove all duplicate billing records:** Duplicate records represented fewer than 0.1% of the records in the data.
  - **Combine participant data with billing records:** We merged AMI data with the customer-specific (account-level) data, including measure installation dates. We then assigned pre- and post-participation treatment billing periods based on those dates. We assigned billing periods before the first measure installation date to the pre-participation period, all bills following the last measure installation date as the post-participation period, and any bills occurring between installation dates (or in the month of the audit and measure installations) to a "dead-band" period that was not included in the analysis.

After individual billing records were cleaned and all data were combined, we removed accounts that did not meet certain criteria. We used these criteria to ensure that all accounts in the final analysis file had sufficient data to allow for robust analysis. Customers who did not meet the criteria necessary for accurate modeling were dropped from the analysis, but later included when calculating total results.

- **Extremely high or low ADC:** We removed customers with entire pre- or post-participation periods having very high or very low usage. We dropped households with energy use at or below 2 kWh/day on average (across their billing history in both the pre- and post-participation periods). We also dropped customers with extremely high usage (more than 300 kWh/day). These households with odd usage patterns are likely the result of factors that cannot easily be controlled for and could bias the results of the model.
- **Inadequate billing history before or after program participation:** The primary savings measures are expected to generate energy savings throughout the year. To be able to fully assess changes in consumption due to program measures before and after installation, we included participants with a billing history covering, at a minimum, 9 months of records before the first day of program participation and 3 months after participation for our treatment group (e.g., current program participants).
- **Participated in other Duke Energy program:** We defined cross-participation two ways: participants who received only home energy reports or received only light bulbs through another DEO program, and participants who received other program benefits. These other program benefits included appliance rebates, direct-install measures, and education. Given the limited number of participants in the treatment group for both years, we chose to include participants in the analysis who received only lighting measures or only home energy reports, while removing those participants who received the other program benefits with deeper savings potential.

Table D-1. shows how many accounts were removed from the analysis based on exclusion criteria listed above.

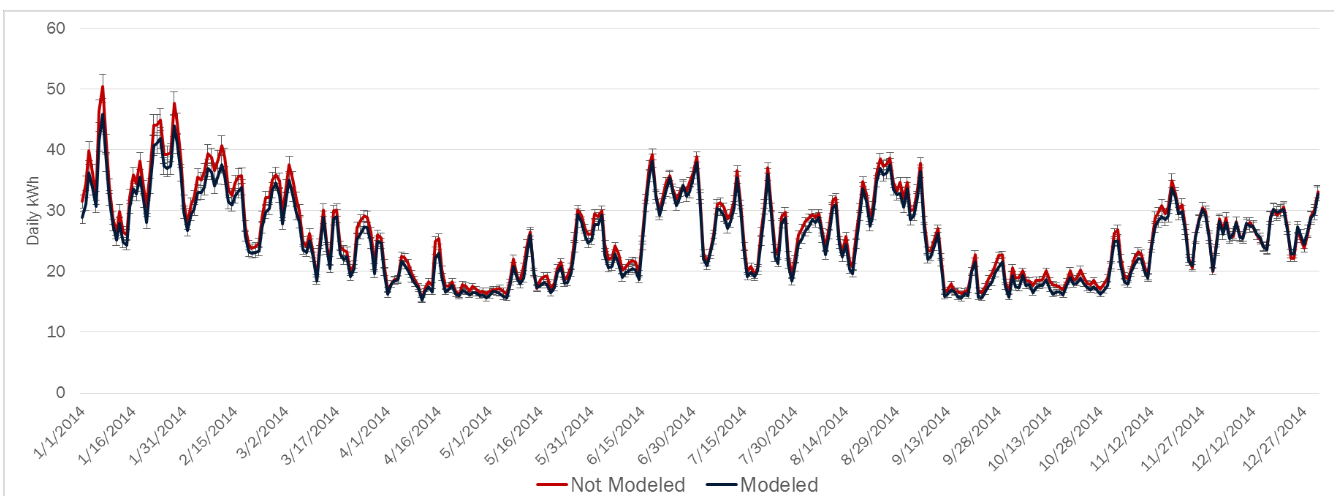
Table D-1. Accounts Removed from Analysis

Exclusion Criteria	Specific Reason for Dropping Account	2015	2016
Total Unique Accounts		**1,362**	**1,314**
Missing Data	AMI Data Not Available	52	586
Participated in Other Programs	Cross-Participation	569	252
Inadequate Billing History	Account Has 3 Months or Larger Gap in Data	1	1
	Less Than 2 Summer Months in Pre-Participation Period	182	68
	Less Than 3 Months in Post-Participation Period Days (Treatment)	67	36
	Less Than 9 Months in Pre-Participation Period Days	39	60
High/Low ADC	Low Overall ADC < 2 kWh	18	6
	Low Overall Post-Participation Period ADC < 2 kWh	4	4
	Low Overall Pre-Participation Period ADC < 2 kWh	6	2
Total Accounts in Final Analysis		**423**	**297**

Since our analysis removed a substantial number of participants from each program year for cross-participation or insufficient data, as seen in Table D-1.**Error! Reference source not found.**, we are not able to model these years separately. To ensure that modeled results apply to the total population of participants, we carefully examined available data to assess any potential differences between participants who were included in the model and those participants who were not. We assessed the equivalency on the following characteristics:

- **Weather:** All weather data are from the same weather station. As such, weather is equivalent for all participants.
- **Baseline period ADC:** We find that participants who were not included in the model were very similar to those who were included in terms of pre-participation period energy consumption (2014).

Figure D-2. Pre-Participation Energy Use for Modeled and Not Modeled Participants



Append Weather Data

To include weather patterns in our model, we used daily weather data from numerous weather stations across the DEO territory, 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 and historical periods) based on average daily temperatures, using the same formula used in weather forecasting.[19] We merged daily weather data into the billing dataset so that each billing period captures the HDD and CDD for each day within that billing period (including start and end dates[20]). For analysis purposes, we then calculated average daily HDD and average daily CDD, based on the number of days within each billing period.

Assess Comparison Group Equivalency

A key challenge for estimating energy savings via a billing analysis is the identification of an appropriate comparison group or "counterfactual" to represent a baseline for what participants would have done (and how much energy they would have consumed) in the absence of the program. There are two key considerations in the design of a comparison group. A comparison group must: 1) have similar energy usage patterns (compared to participants) before participation (i.e., in the 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 control group would be equivalent to the treatment group in all aspects, save for the treatment being evaluated (participation in the NES program in our case). A perfect post-participation match is impossible when studying the effects of energy efficiency programs, since we cannot know if any group of nonparticipants is equivalent to the participant group, especially in the dimension of what the participants would have done absent the program. We generally aim to use a comparison group that, on average, exhibits very similar usage patterns prior to participation. Achieving this ensures 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 environment. Since a comparison group represents the counterfactual, results from the billing analysis are net results, and application of a NTGR is unnecessary. Overall, the comparison group should capture a similar rate of customers who would be free-riders if they had participated. Additionally, due to the nature of the program, we anticipate that free-ridership for participants is low. This comparison group represents potential future participants, which brings along the assumption that these customers possess many of the same attributes as the treatment group and have a similar propensity to participate in a low-income targeted energy efficiency program.

To construct a comparison group, we gathered data for all customers in neighborhoods that will be targeted in the next program year. Based on a comparative analysis of pre-participation period kWh consumption of and weather experienced by the treatment group and potential comparison group, we found that customers from the neighborhoods that will be targeted in 2017 are a suitable comparison for 2015–2016 participants. We analyzed two critical criteria to determine if participants were equivalent to the potential comparison

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[19] 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 2.) If the mean temperature for the day is 5° higher than 75, then there have been 5 CDD. On the other hand, if the weather has been cool, and the mean temperature is, say, 55°, then there have been 10 HDD (65 minus 55). http://www.srh.noaa.gov/ffc/?n=degdays.

[20] 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.

participants, and therefore whether the potential comparison customers could be used as a valid comparison group. These criteria are:

- **Weather:** We compared average daily HDD and CDD and found that participants in the treatment group experienced the same weather over time as the comparison group. The same weather station was used for all customers included. Graphs of the HDD and CDD experienced by these customers are shown in Figure D-3 and Figure D-4, respectively.

Figure D-3. Average Heating Degree Days

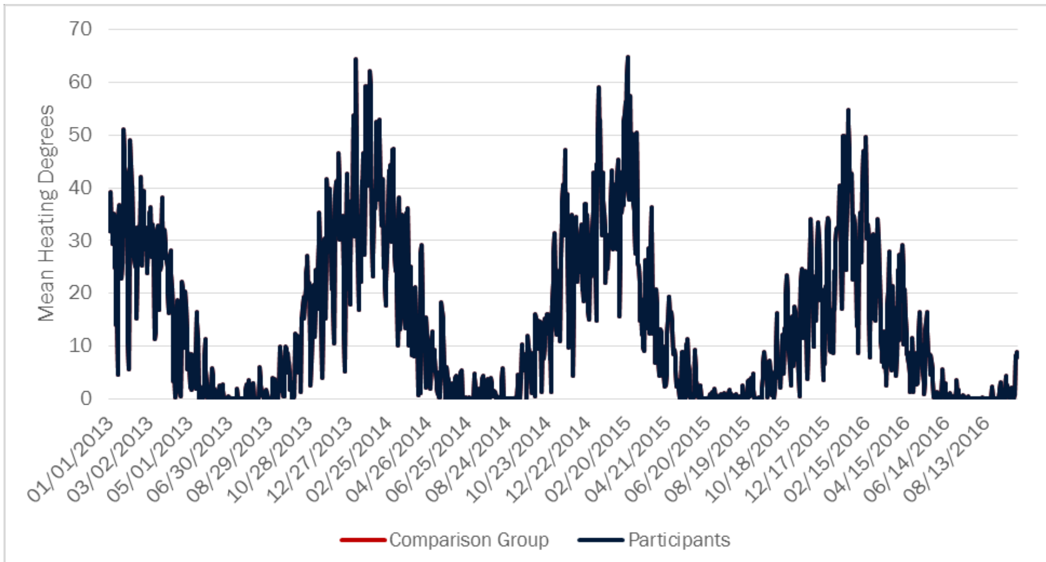
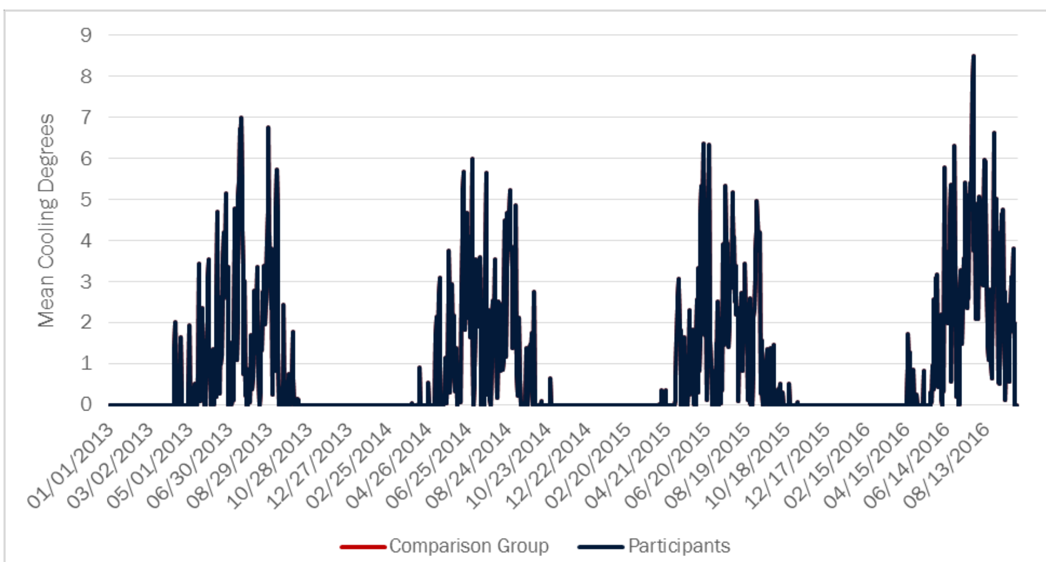
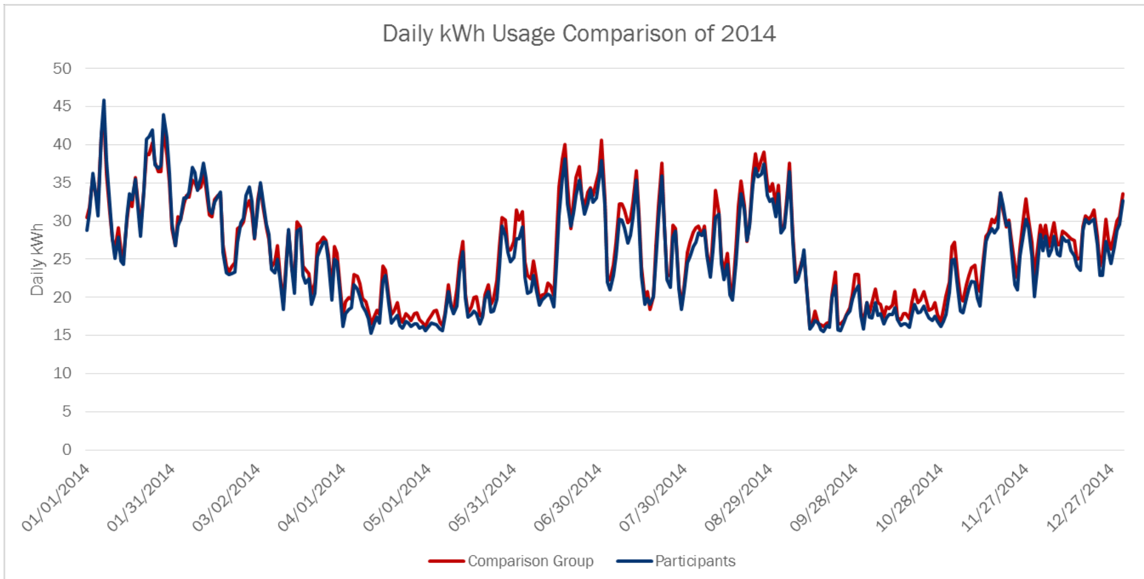


Figure D-4. Average Cooling Degree Days



- **Baseline period ADC:** Similarity in ADC before engaging with the program might be a general proxy for behavioral similarities. We compared the baseline ADC of participants in each group and found pre-participation energy usage of our potential comparison group follows a nearly identical pattern as that of the treatment group (Figure D-5).

Figure D-5. Comparison of Average Daily kWh Consumption between Treatment and Comparison Customers



Model Program Impacts

To estimate savings for the NES program, Opinion Dynamics used a LFER model that incorporates weather and monthly changes in energy usage, as well as interaction terms that show the effect of these factors in the post-participation 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 tested a multitude of possibilities, all of which utilized the comparison group.

Develop Model Specifications

Our final models were judged by 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 overall R-squared, which gives an estimate of how much the model explains. An R-squared of 1.0 would represent a model that explains 100% of the variance in the dependent variable, and an R-squared of 0.5 would explain 50%. In our quasi-experiment, R-squared will appear low because of our use of fixed effects. A higher R-squared relative to other potential models will still be a significant factor in selection of a final model. We also compared Akaike Information Criterion (AIC) values of each model specification within the same dataset. The AIC provides a measure of relative quality between models; a lower value indicates a relatively more efficient model.

Our final method utilizes a comparison group to construct a counterfactual baseline (what participants would have done during the post-program period absent the program) for the treatment group in the post-program period. To construct the comparison group, we gathered data for all customers in neighborhoods that will be targeted in 2017. As previously mentioned, we did not include customers who participated in other programs, with the exception of customers who received only a small number of CFLs from some other program, or received a home energy report. We considered not removing these customers, and entering indicator variables for each of the other utility programs. Doing this could lead to interference between the influences of each program on energy use, making it difficult to draw valid conclusions about the effects of NES program participation separate of the other programs. As such, we believe that it is more appropriate to remove those customers from the analysis. The removal of households that participated in other Duke Energy programs, in addition to the assumption that free-ridership for a program of this nature is zero, supports our confidence in saying that the treatment effect found here is representative of the change in energy use caused by the NES program alone.

In the development of our model, we investigated average energy consumption before and after participation, how changes in weather affected the amount of energy used, and differences in energy use in each month. In this investigation, we found a clear linear relationship between energy use and weather, and expected fluctuations in energy use through the year.

To control for seasonal changes in energy use, our model includes terms for each month of the year (January–December). This allows a month to be present in both the pre-participation period and the post-participation period, thus capturing the change in usage during that month. Our use of these monthly terms in conjunction with a comparison group creates an improved counterfactual and increases the accuracy of program savings estimates. We also included interactions of the treatment with monthly terms to control for any inconsistencies that are not observable between the treatment and comparison groups.

We included interaction terms of weather and the post-participation period to account for the relationship between weather and consumption following treatment, as well as interactions with month indicators and the post-participation period. The inclusion of these terms is meant to account for non-program-related changes that occur during the post-participation period, for example, the warmer summers that have recently been experienced. Failure to control for these potential changes could undervalue the treatment effect.

Test Model Specifications and Fit to Select Best Model

Of all the models we tested, we found the model in Equation D-1 to have the best overall fit. The model takes into account changes in weather (HDD and CDD) monthly, before and after participation, and includes interaction terms of weather with the post-participation period, in order to model differences in the impact that weather had on energy savings after participation. As a proxy for each account's normal rate of energy consumption prior to the program, we included its ADC during 2014 to control for potential differences in the magnitude of energy used between participants of the two program years.

Equation D-1. Model Specification

$$ADC_{it} = B_h + B_1 Post_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_4 Post \cdot HDD_{it} + B_5 Post \cdot CDD_{it} + B_t Month + B_{t1} Month \cdot Post + B_{t2} Month \cdot Treat + 2014kWh * Post + \varepsilon_{it}$$

Where:

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

$Post$ = Indicator for treatment group in post-participation period (coded "0" if treatment group in pre-participation period or comparison group in all periods, coded "1" in post-participation period for treatment group)

HDD = Average daily heating degree days from NCDC

CDD = Average daily cooling degree days from NCDC

$Month$ = Month indicator

$Treat$ = Indicator for treatment group participants

$2014kWh$ = Average energy use (daily kWh) during 2014 for each account

B_h= Average household-specific constant

B_1= Main program effect (change in ADC associated with being a participant in the post-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= Increment in ADC associated with each increment increase of HDD for participants in the post-program period (the additional program effect due to HDD)
B_5= Increment in ADC associated with each increment increase of CDD for participants in the post-program period (the additional program effect due to CDD)
B_t= Coefficients for each month
B_{t1}= Coefficients for each month in the post-participation period
B_{t2}= Coefficients for each month for treatment groups participants
ε_{it} = Error term

Estimate Net Savings and Calculate Net Realization Rate

This section contains the observed net savings and realization rates resulting from the billing analysis of 2015 and 2016 participants. The results here do not specifically account for free-ridership, but do reflect savings associated with installed measures, spillover, and potential behavioral changes from energy efficiency knowledge gained during the assessment. Free-ridership is assumed to be 0.

The regression model results presented in Table D-2 show a reduction in electricity use after customers participated in the NES program, controlling for weather, time, and the household characteristics for each participant (reflected in the household-specific constant terms).

Table D-2. Final Model

Variable	Coefficient
Post (NES program participation)	1.646*
CDD	3.695**
HDD	0.329***
Post-participation period CDD (interaction of Post x CDD)	−0.590**
Post-participation period HDD (interaction of Post x HDD)	0.0316
Average 2014 Energy Use	−0.133***
Constant	18.86***
Observations	3,159,813
R-squared	0.552

* p<0.1, ** p<0.05, *** p<0.01.

Due to the post-participation period weather interaction terms in the model, it is necessary to calculate the treatment effect by multiplying the average degree-day value and the coefficient for each interaction term and adding that to the coefficient for the main effect term (Post) in the model. Evaluating the equation at the mean values of HDD and CDD, as shown in Equation D-2, we can estimate the overall savings associated with the program.

Equation D-2. Model Evaluation

$$\Delta ADC = B_1 Post + AvgPostHDD_t \cdot (B_2 Post \cdot HDD) + \ AvgPostCDD_t \cdot (B_3 Post \cdot CDD)$$

Where:

ΔADC = Change in average daily consumption

$AvgPostHDD_t$ = Average number of HDD during month t of the post-participation period
$AvgPostCDD_t$= Average number of CDD during month t of the post-participation period

Table D-3. Adjusted Estimate of Daily Program Savings*

NES Estimate (ΔADC)	Standard Error	T	P>|t|	90% Confidence Interval	
				Lower	Upper
−0.83	0.253	−3.282	0.000	−1.2	−0.4

* Daily savings estimate is the inverse of the coefficient for NES program participation in each respective model.

The value of the NES program estimate seen in Table D-3 represents a 0.83 kWh reduction in ADC associated with moving from pre-participation treatment to post-participation treatment. There is a 90% probability, or confidence, that actual overall first-year program savings fall between 0.4 kWh and 1.2 kWh per day for NES program participants. These savings estimates are extrapolated to the overall net program savings for DEO NES program participants (Table D-4). We estimate that the average realized annual savings are 303 kWh for customers who participated in the NES program in 2015 and 2016. To better facilitate comparisons of program performance across program years and territories, we also show savings here as a percentage of energy saved with respect to the treatment group's baseline. The baseline usage is calculated using the coefficients from the model that do not feed into the treatment effect. This calculation shows the energy that customers would have used on average if they did not participate, i.e., the counterfactual. To estimate the percent savings from participant's baseline energy consumption, we divide the change in daily electricity use for the NES program by the mean baseline ADC.

Table D-4. Estimated Annual Savings from Billing Analysis

Baseline Energy Use		Energy Savings		
Daily (kWh)	Annual (kWh)	Daily (kWh)	Annual (kWh)	Savings (%)
25.7	9,381	0.83	303	3.2%

Complete Model Results

Linear regression, absorbing indicators		
	Number of obs	3,159,813
	F(39, 2539)	164.07
	Prob > F	0.0000
	R-squared	0.5521
	Adj R-squared	0.5517
	Root MSE	14.4971

(Std. Err. Adjusted for 2,540 clusters in account)

Δ kWh	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
Participation	1.645842	0.922999	1.78	0.075	-0.164065	3.455748
CDD	3.695093	0.053740	68.76	0.000	3.589714	3.800472
HDD	0.328946	0.010580	31.09	0.000	0.308199	0.349693
Post-Period CDD	-0.589574	0.124515	-4.73	0.000	-0.833735	-0.345414
Post-Period HDD	0.031587	0.025374	1.24	0.213	-0.018169	0.081344
*2014 kWh * Post-Period*	-0.132871	0.024288	-5.47	0.000	-0.180497	-0.085244
Months						
January	-0.849487	0.075897	-11.19	0.000	-0.998314	-0.700660
February	-2.264253	0.133952	-16.90	0.000	-2.526919	-2.001587
March	-4.382165	0.205208	-21.35	0.000	-4.784557	-3.979773
April	-2.770284	0.261447	-10.60	0.000	-3.282954	-2.257613
May	1.578804	0.322348	4.90	0.000	0.946713	2.210895
June	3.160363	0.332908	9.49	0.000	2.507564	3.813161
July	2.935027	0.327677	8.96	0.000	2.292486	3.577568
August	-0.875209	0.293722	-2.98	0.003	-1.451167	-0.299251
September	-4.026290	0.237639	-16.94	0.000	-4.492275	-3.560304
October	-2.579785	0.167778	-15.38	0.000	-2.908782	-2.250789
November	-0.345513	0.112178	-3.08	0.002	-0.565482	-0.125543
December						
Months * Treatment Group						
January	0.440207	0.320722	1.37	0.170	-0.188696	1.069111
February	0.726480	0.325379	2.23	0.026	0.088445	1.364516
March	-0.075545	0.245953	-0.31	0.759	-0.557833	0.406743
April	-0.118524	0.520612	-0.23	0.820	-1.139390	0.902343
May	0.064111	0.683399	0.09	0.925	-1.275965	1.404188
June	-0.389443	0.856994	-0.45	0.650	-2.069921	1.291036
July	-0.806546	0.895275	-0.90	0.368	-2.562090	0.948998

August	-0.629932	0.899676	-0.70	0.484	-2.394104	1.134241
September	-0.522701	0.779441	-0.67	0.503	-2.051106	1.005703
October	-0.246695	0.591507	-0.42	0.677	-1.406580	0.913191
November	0.282056	0.244766	1.15	0.249	-0.197905	0.762018
December	0.000000	(omitted)				
Months * Post-Period						
January	0.154309	0.353722	0.44	0.663	-0.539303	0.847921
February	-0.569893	0.448474	-1.27	0.204	-1.449305	0.309520
March	-0.116770	0.416244	-0.28	0.779	-0.932983	0.699442
April	1.147412	0.533110	2.15	0.031	0.102037	2.192787
May	0.666751	0.622678	1.07	0.284	-0.554257	1.887759
June	0.920162	0.759682	1.21	0.226	-0.569498	2.409822
July	2.307351	0.818192	2.82	0.005	0.702959	3.911742
August	0.973036	0.830590	1.17	0.242	-0.655667	2.601740
September	2.254844	0.745758	3.02	0.003	0.792488	3.717200
October	1.673206	0.573097	2.92	0.004	0.549421	2.796990
November	-0.366221	0.301741	-1.21	0.225	-0.957905	0.225463
December	0.000000	(omitted)				
Constant	18.859900	0.166228	113.46	0.000	18.533950	19.185860

account absorbed (2,450 categories)

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