AUGUST 30, 2018

Impact Evaluation

National Grid Rhode Island Income Eligible Services

Developed For

National Grid

40 Sylvan Road

Waltham, MA 02451

Developed By

Cadeo Group

107 SE Washington Street, Suite 450

Portland, OR 97214

CONTENTS

Introduction

This report details the findings from Cadeo's impact evaluation of National Grid's 2015 and 2016 Income Eligible Services (IES) program for single family customers in Rhode Island.

About Income Eligible Services

National Grid Rhode Island offers IES to help low income families and individuals reduce their electric and gas bills by insulating their homes, replacing inefficient appliances and products, and providing energy efficiency education. The IES program provides eligible customers with home energy assessments and energy saving measures to improve the efficiency and comfort of their homes, free of charge.

Income eligible single family customers are those who live in one- to four-unit buildings and those who are enrolled in National Grid's fuel discount rate plans (A-60 Electric Low-Income rate and/or 1301 Low-Income Heat rate). Customers who qualify for the Low-Income Home Energy Assistance Program (LIHEAP), also known as "fuel assistance" are also eligible to participate in IES.

Program participants are offered home energy assessments with educational materials and direct installation of energy-saving measures such as efficient lighting, smart power strips and room AC timers. Program participants may also qualify to receive weatherization measures (regardless of their heating fuel—gas, electric or delivered duels), as well as heating system replacement, the removal or replacement of inefficient appliances, and domestic hot water measures.

The IES program is delivered by Rhode Island's territory-based Community Action Agency Program agencies and local contractors. The IES program works in close collaboration with the State of Rhode Island Department of Human Services weatherization program and LIHEAP, overseen by the federal Department of Energy and Department of Human Services, respectively.

Program Summary

In 2015 and 2016, IES completed approximately 4,600 home energy assessments and installed more than 130,000 energy efficiency measures. Table 1 lists the number of each measure installed by IES during these two years, as well as the per-unit ex ante savings associated with each measure. For almost all measures, National Grid's ex ante savings come from the previous IES impact evaluation[1], which was completed in 2014 and assessed savings for program years 2011 and 2012. Notable exceptions to this trend are the program's lighting measures. For lighting measures, National Grid used the results of a residential lighting Market Adoption Model (MAM) to develop ex ante values for IES.

[1] http://rieermc.ri.gov/wp-content/uploads/2018/03/national-grid-rhode-island-income-eligible-services-impact-evaluation-volume-ii.pdf

Table 1. 2015 and 2016 Participation and Per-Measure Ex Ante Savings

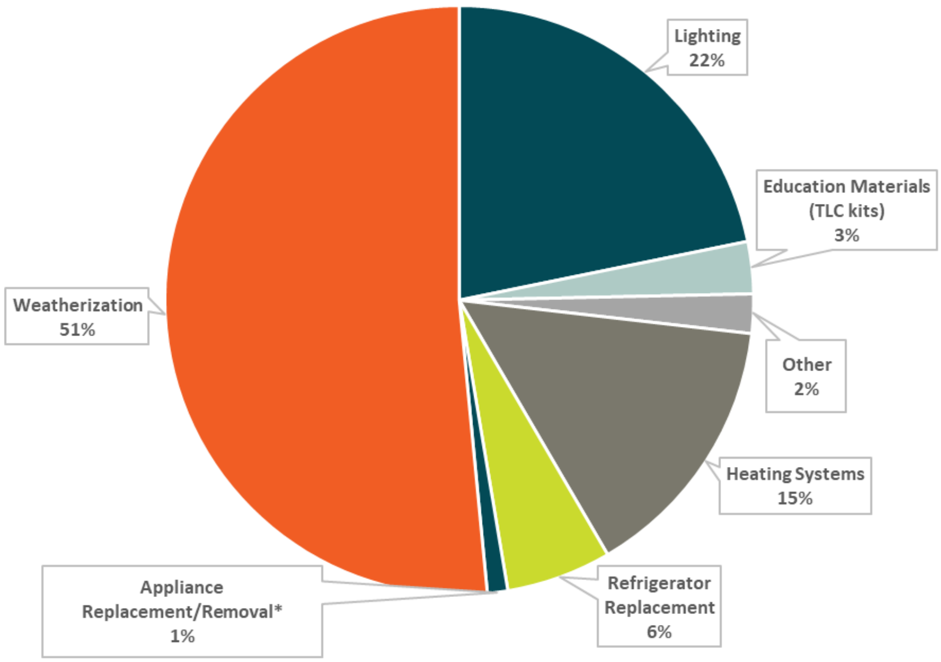
	Electric (kWh)		Natural Gas (Therms)		Oil (MMBTU)		Propane (MMBTU)	
IES Measure	n	Savings	n	Savings	n	Savings	n	Savings
AC Replacement (Window Unit)	925	100						
AC Timer	196	0						
Appliance Removal (Refrigerator or Freezer)	16	1,180						
Domestic Hot Water (Aerators or Showerheads)	13	134	36	9	4	0.7		
Education Materials (TLC kits)	4,603	138						
Freezer Replacement	285	484						
Heat Pump Water Heaters	1	1,775						
Heating Systems			362	184	241	18.4	5	18.4
CFL	21,846	45						
LED Bulbs	77,183	39						
LED EISA EXEMPT	11,147	52						
LED Reflectors	5,082	57						
Refrigerator Replacement	3,336	384						
Smart Strip	6,264	75						
Waterbed	3	872						
Weatherization	48	1,616	846	188	670	28.1	23	28.1

To understand how each of these measures contributed to IES' overall savings, Cadeo (also referred to as the evaluation team) applied the program's per-unit ex ante savings to the 2015–16 IES measure counts. To add clarity, the team also aggregated the 16 measures in Table 1 into the following 7 different measure groups:

- **Weatherization**
- **Lighting**. CFL, LED Bulbs, LED EISA EXEMPT, and LED Reflectors
- **Heating Systems**
- **Refrigerator Replacement**
- **Appliance Replacement/Removal (other than refrigerators).** AC Replacement, Appliance Removal, and Freezer Removal
- **Education Materials/TLC Kits**
- **Other**. Domestic Hot Water, Heat Pump Water Heaters, Smart Strips, Waterbed, AC Timer

Figure 1 compares the total ex ante savings generated by each measure category in 2015–16. To enable comparison savings across fuels, the team converted all savings into MMBTU. Based on the program's per-unit ex ante savings and reported participation, IES saved 75,742 MMBTU in 2015 and 2016.[2]

Figure 1. Savings by Measure Category (MMBTUs in 2015 and 2016)

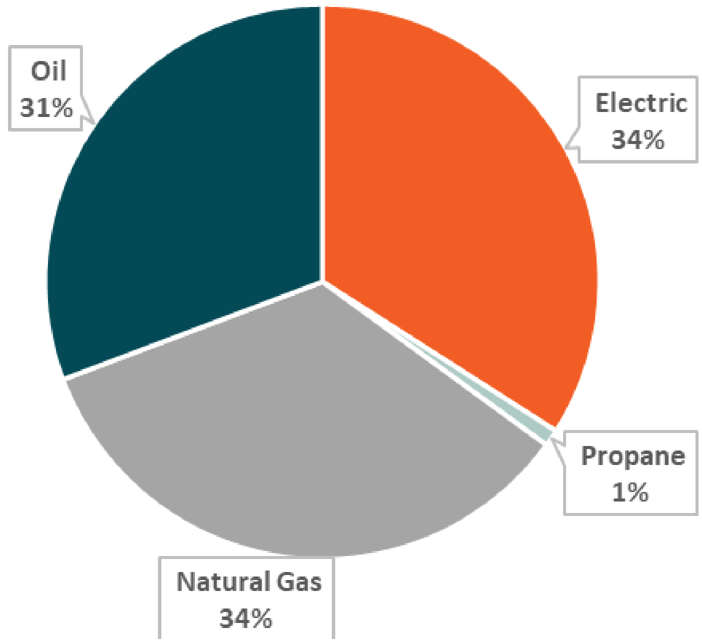


As shown above, just over half of the program's savings came from weatherization alone. In total, weatherization, lighting, heating systems, and refrigerator replacement constituted 94% of IES' total ex ante savings in these two years. Consequently, the evaluation team focused its efforts on these measure categories.

The team also investigated how each fuel type served by IES—electricity, natural gas, oil, and propane—contributed to the program's overall savings. As evident in Figure 2, IES' electric, natural gas, and oil savings contributed relatively equally to the program's overall ex ante savings.

[2] This total represents the primary savings associated with each measure. That is, the total does not include additional savings generated by some measures, such as the electric furnace fan savings resulting from weatherization.

Figure 2. Savings by Fuel (MMBTUs in 2015 and 2016)



Study Objectives

National Grid established three objectives for the 2015 and 2016 IES impact evaluation:

- Estimate the overall average energy savings attributable to the IES program
- Provide credible energy savings and realization rates for each electric, natural gas, propane and heating oil measures and/or measure groups
- Report findings and observations and provide recommendations on program design to help improve the effectiveness of the program

To meet these three objectives, Cadeo used a combination of billing analysis, technical reference manual-based (TRM) engineering algorithms and building simulation modeling.

Key Terminology

The evaluation team uses the language defined in Table 2 throughout the report to explain key impact evaluation concepts.

Table 2. Summary of Key Evaluation Terminology

Term	Definition
Participant	An individual or household (also identified by a unique account number) who receive at least one IES measure (such as a TLC kit, CFL or LED lighting, a refrigerator replacement, and/or a heating system replacement).
Ex Ante Savings	Savings assumed by National Grid prior to an evaluation, usually based on the prior IES impact evaluation and/or the Rhode Island TRM.
Ex Post Savings	Savings determined through this evaluation.
Treatment Group	The IES participants for whom the team estimated ex post savings: customers who received IES measures in program year 2015 or 2016. The treatment group for the billing analysis was limited to IES participants prior to October 2016, to ensure a full heating season in the post-installation period after accounting for a blackout period around the measure installation date.[3]
Control Group	The set of customers used in a billing analysis to serve as a counterfactual for estimating the program's impact. The control group accounts (or controls) for exogenous factors such as moves and rate changes that can otherwise obscure program-generated savings. In the context of this evaluation, the team used future IES participants (i.e., IES participants in 2017) as the control group.
Weatherization	A general term used to describe air sealing and/or insulation (one of more of attic, wall, or floor insulation). References to air sealing or insulation in the report are specific to that measure, whereas weatherization refers to one or both measures.

[3] For the billing analysis, the team began each participant's post-installation period with the second full billing cycle after the participant's final measure installation date, which allows for at least one full month of "transition time" between pre- and post- period.

How to Use the Results of this Evaluation

We present the results of this evaluation in three parts: An **Evaluation Summary,** a **Supporting Documentation workbook,** and an **Appendix**.

The **Evaluation Summary,** which this section is part of, summarizes the results of the evaluation and briefly outlines the evaluation methodologies used. For key IES measures, such as lighting, refrigerator replacement, weatherization and heating system replacement, the Evaluation Summary includes a more detailed explanation of how the team calculated ex post savings. The Evaluation Summary does not, however, include details such as the engineering algorithms and the specific primary and secondary data used to develop ex post savings for other measures.

For these types of details, users of this evaluation should rely on the second evaluation output: **Supporting Documentation workbook**. This Excel workbook includes additional details about all aspects of this evaluation. Specifically, the workbook includes the detailed regression results (parameters, coefficients, and standard errors) for both the natural gas and electric billing analyses. It also includes a tab for each IES measure that was evaluated using an engineering approach (algorithms or building simulation). For measures assessed using an algorithmic approach, the workbook details the Rhode Island TRM engineering algorithm used to evaluate that measure and the values (and sources) for all inputs used in that algorithm. Each measure-specific worksheet also includes a direct comparison of ex ante and ex post savings. Each of these tabs link to common participant, housing stock, and engineering assumptions to ensure consistency across measures and transparency. Readers interested in accessing the Supporting Documentation Workbook should request access from the IES evaluation manager.

The third and final part of this evaluation is the **Appendix,** which contains the original work plan (Appendix A) and the data review and analysis plan (Appendix B) deliverables that the evaluation team created as part of this study.

Methodology

Overview

The evaluation team relied on three complementary evaluation methodologies: billing analysis, engineering algorithms, and building simulation. Table 3 briefly summarizes each methodology. The analysis plan (Appendix B) describes each methodology in greater detail.

Table 3. Summary of Evaluation Methodologies

Methodology	Details
Billing Analysis	• Used to report ex post savings when measure-specific billing analysis results met pre-determined threshold of better than ±25% precision at the 90% confidence level • Combined customer billing records with weather and measure installation data (for both IES and non-IES funded measures) to get a complete perspective of each customer's energy consumption drivers • Conducted a structured screening process to ensure that the model uses only those customers with sufficient billing data and without spurious billing records • Matched each treatment group customer to a control group (future IES participants) customer with a similar, monthly, preinstallation period energy consumption pattern • Specified and refined a monthly post-program regression (PPR) model • Generated results, which were weather-normalized (where applicable) using 30-year historical weather data from three different weather stations across Rhode Island; each IES participant was mapped the closest weather station
Engineering Algorithms	• Relied primarily on the algorithms documented in 2018 Rhode Island TRM[4] • Relied on recent studies from other jurisdictions (notably Massachusetts and Ontario) where the Rhode Island TRM did not specify a savings algorithm or specific input value • Leveraged detailed IES program data to calculate baseline and efficient cases for each measure • Relied on regionally appropriate secondary data sources and other relevant studies when IES program data was not collected or unavailable (sources included the most recent low income impact evaluation in Massachusetts5, Residential Energy Consumption Survey, ENERGY STAR® standards, Building America Benchmark Program Database, etc.) • Included a literature review of recent studies, relevant US Department of Energy appliance standards, other state TRMs, and similar evaluations in other states

[4] http://www.ripuc.org/eventsactions/docket/4755-NGrid-2018-TRM-RI.pdf

[5] http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Program-Impact-Evaluation_Part-of-the-Massachusetts-Residential-Retrofit-Low-Income-Program-Area-Evaluation.pdf

Methodology	Details
Building Simulation	• Modeled using BEopt (Building Energy Optimization) software developed by the National Renewable Energy Laboratory • Constructed baseline home geometry and building characteristics based on IES data; inputs like square footage, number of floors and bathrooms, and weather profile were all informed by IES program data • Leveraged a similar building model used during the 2018 MA Home Energy Services impact evaluation for inputs that could not be estimated through program data • Simulated ten different scenarios reflecting various building types (e.g., one-story detached, low-rise multi-unit), heating fuels, heating system combinations, and cooling scenarios • Calibrated each model using IES participant billing data • Disaggregated billing data into specific end uses (heating, water heating, and baseload) • Weighted the result of the ten models into a statewide average using the building type, heating fuels, heating type, and cooling type characteristics of 2015 and 2016 IES customers

Data Sources

To inform the evaluation team's analysis, National Grid provided four data sources that characterized the IES program energy-efficiency improvements and other characteristics of the program's participants.

- **IES Measure Data**. Included basic customer information (account number, ZIP code, heating fuel type) and measure (measure type, quantity, and ex ante savings) for 2015, 2016, and 2017 participants, the latter of whom we used as a control group in the billing analysis.
- **Supplemental Participant Data**. Provided additional information regarding the number of units in participating buildings, as well as the type (central or room), size (number of BTUs), and number of cooling systems present in participating customers' homes. In a separate file, National Grid also provided detailed information (e.g., age, size, configuration) about the inefficient appliances that were removed or replaced through IES.
- **Non-IES Measure Data.** Contained information regarding the energy efficiency measures, as well as health and safety improvements, made in IES customer homes that were not funded by National Grid. These measures and/or improvements were funded by one of the following sources: Department of Energy Weatherization Assistance Program (DOE WAP) or Health & Human Service Weatherization Assistance Program (HHS WAP).
- **Billing Data**. Provided electric and natural gas energy consumption data for customers between January 2014 to April 2018. The raw dataset includes energy usage of both program participants and future program participants, along with other variables such as billing cycle dates, customer type, and billing rate type. The team did not attempt to gather any information regarding delivered fuels (i.e., heating oil and propane).

In addition to the four data sources already listed, the evaluation team acquired weather data from NOAA (National Oceanic and Atmospheric Administration):

- **Weather Data**. The evaluation team assigned weather data to each National Grid participant based upon the NOAA weather station closest to the participant's ZIP code. Thus, each participant's heating and cooling degree days used in the analysis are specific to the area for which their billing data is associated. The evaluation team used Providence, Block Island[6], and North Central State Airport weather stations for this analysis.

[6] The Block Island weather station is not in National Grid's service territory, but it is the closest weather station to a small amount of IES participants.

Results Summary

Table 4 presents the ex post results for each evaluated IES measure. The table also indicates which methodology the evaluation team used to estimate ex post savings.

The team used engineering algorithms to evaluate most measures, while the billing analysis was limited to a small subset (i.e., lighting, refrigerator replacement, natural gas weatherization, and natural gas heating system replacement), where the evaluation team could report savings at better than ±25% precision at the 90% confidence all level.

As noted previously, several of the measures listed in Table 4 were not offered by National Grid in 2015 and 2016. The evaluation team included these measures as part of this study, at National Grid's request, to inform IES planning efforts.

Table 4. IES PY 2015-2016 Ex Post Savings by Measure and Fuel

IES Measure	Electric (kWh)	Natural Gas (Therms)	Oil (MMBTU)	Other (MMBTU)
AC Replacement (Window Unit)	71	N/A	N/A	N/A
AC Timer	0	N/A	N/A	N/A
Appliance Removal (Refrigerator or Freezer)	1,036	N/A	N/A	N/A
Clothes Washer and Dryer**	Various (See Workbook for Details)			
Dehumidifiers Replacement**	1,106	N/A	N/A	N/A
Domestic Hot Water (Aerators or Showerheads)	160	8	0.9	0.8
Education Materials (TLC kits)	21	N/A	N/A	N/A
Freezer Replacement	333	N/A	N/A	N/A
Heat Pump Water Heaters	814	N/A	N/A	N/A
Heating Systems	N/A	79	7.8	7.9
Furnace Fan (due to heating system replacement), **kWh**	N/A	16	10	16
CFL	18*	N/A	N/A	N/A
LED Bulbs		N/A	N/A	N/A
LED EISA EXEMPT		N/A	N/A	N/A
LED Reflectors		N/A	N/A	N/A
Programmable Thermostats**	232	34	3.4	3.4
Electric savings (Fan savings and cooling savings for CAC), **kWh**	18.8	11.2	8.7	11.2
Refrigerator Replacement	467	N/A	N/A	N/A
Smart Strip	75	N/A	N/A	N/A
Waterbed	872	N/A	N/A	N/A
Weatherization	1,201	124	12.6	12.4
Furnace Fan Savings, **kWh**	N/A	63	65	63
Cooling Savings, **kWh**	78	30	30	30

*Note: 18 kWh represents the average per-bulb savings estimate for all lighting measures

**Added to IES after 2016 or under consideration for future inclusion; not offered as part of IES during 2015 and 2016

Key

Teal	Billing Analysis
Light grey	Engineering Algorithm
Orange	Building Simulation

Table 5 and Table 6 compare the ex post savings presented in the previous table with the program's ex ante savings. Table 5 focuses on electric measures, while Table 6 compares natural gas, oil, and propane measures. Both tables include a brief explanation of why ex ante and ex post savings may differ. Also, both tables are limited to the measures installed in 2015 and 2016 and focus on the primary savings associated with each measure. Information about changes in the savings associated with measure's other energy impacts (e.g., electric furnace fan savings resulting from weatherization) is provided in the Supporting Documentation workbook.

Table 5. Comparison of Ex Ante and Ex Post Savings – Electric Measures (kWh/year)

IES Measure	Ex Ante	Ex Post	Realization Rate	Details
AC Replacement (Window Unit)	100	71	71%	Updated effective full loads hours reduced savings relative to ex ante (previous estimate based on central air conditioner usage, not a window unit). However, a lower baseline efficiency (to reflect in situ conditions) offset overall decrease.
Appliance Removal (Refrigerator or Freezer)	1,180	1,036	88%	Applying the Uniform Methods Protocol appliance recycling protocol, using IES-specific appliance characteristics, yielded similar - but somewhat lower - savings relative to ex ante, which was a leveraged value from Massachusetts.
Domestic Hot Water (Aerators or Showerheads)	134	160	120%	The evaluation weighted the number of installs based on program data; showerhead savings increased the average significantly, as they were the more prevalent DHW measure in 2015-2016
Education Materials (TLC kits)	138	21	15%	The ex ante savings were based on the previous evaluation's finding that whole-home electric savings (via billing analysis) were above and beyond the aggregated measure-specific savings for electric measures. The current evaluation did not produce a similar finding so the ex post savings reflect savings associated with kit contents alone.
Freezer Replacement	484	333	69%	Applying the Uniform Methods Protocol appliance recycling protocol, using IES-specific freezer characteristics, yielded similar - but somewhat lower - savings relative to ex ante, which was a leveraged value from Massachusetts.
Heat Pump Water Heaters	1,775	814	46%	The ex ante savings are based on a hot water savings engineering algorithm. The ex post savings estimate was determined using a building simulation, weights for the mix of IES customers in single family detached and multi-unit (2-4) homes, and accounts for additional consumption from home HVAC system.
CFL	45	18	40%	Through billing analysis, the evaluation team found much lower per-unit savings for lighting compared to the ex ante savings, which are based on National Grid's residential lighting Market Adoption Model. However, the team was unable to estimate lighting type-specific (e.g., LED Bulbs, LED EISA EXEMPT) savings through the billing analysis.
LED Bulbs	39		47%	
LED EISA EXEMPT	52		34%	
LED Reflectors	57		31%	
Refrigerator Replacement	384	467	122%	Both the ex ante and ex post savings are billing analysis results. The point estimates from the two evaluation differ by 22%, although the two values are not statistically different; the billing analysis from the current evaluation has the better precision associated with its estimate.
Smart Strip	75	75	100%	The evaluation team confirmed that the ex ante savings relies on the best and most regionally appropriate estimate of smart strips savings. The team does note, shown later in the Recommendations, that National Grid gather information about installation location in the future. This will allow future evaluations to tailor savings estimates for IES.
Waterbed	872	872	100%	Due to limited participation for waterbeds (n=3), the team accepted the ex ante savings as ex post without further analysis.
Weatherization	1,616	1,201	74%	The ex ante savings were based on a leveraged Massachusetts evaluation. The ex post evaluation also leverages a Massachusetts study, albeit a more recent one. It also relies on IES-specific electric heating loads, as determined through the billing analysis.

Table 6. Comparison of Ex Ante and Ex Post Savings – Natural Gas (therms/year), Oil (MMBTU/year), and Propane Measures (MMBTU/year)

	Natural Gas			Oil			Propane			
IES Measure	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Details
Domestic Hot Water (Aerators or Showerheads)	9	8.3	93%	0.7	0.9	127%				Results are generally similar to ex ante. Similar to the electric DHW analysis, the evaluation team weighted the overall DHW savings to reflect the mix of aerators and showerheads reported in the program data.
Heating Systems	184	79	43%	18.4	7.8	42%	18.4	8	43%	The natural gas billing analysis completed as part of the current evaluation yielded much lower savings than the previous evaluation. The results are statistically different between studies, with the current evaluation exhibiting much better precision around its estimate (±11% versus ±33%, primarily due to a larger sample sizes - 235 versus 29). The evaluation team does not have any information about changes to program delivery that would result in much lower average savings.
Weatherization	188	124	66%	28.1	12.6	45%	28.1	12	44%	Similarly, the natural gas billing analysis completed as part of the current evaluation yielded lower and statistically significantly different savings than the previous evaluation. As with heating system replacements, the current evaluation's results are more precise (±5% versus ±33%) and relied on a considerably larger sample of IES participants (785 versus 162). Again, the evaluation team does not have any information about changes to program delivery that would result in lower average weatherization savings.

Using the information above, the evaluation team determined the total ex post savings generated by IES in 2015 and 2016, and recalculated the contribution of each measure category toward the program's total ex post savings (Table 7). The lower per-unit ex post savings shown in the preceding tables for the program's three most important measures – weatherization, lighting, and heating systems – resulted in lower overall savings for IES (41,393 MMBTU/year) relative to the program's ex ante assumptions (75,742 MMBTU/year).

Table 7. Comparison of Ex Ante and Ex Post Savings – Measure Categories and Program Overall (MMBTU)

Measure Category	Ex Ante	Ex Post	Difference	Realization Rate
Weatherization	39,008	21,648	(17,360)	55%
Lighting	16,504	7,074	(9,430)	43%
Heating Systems	11,187	4,769	(6,418)	43%
Refrigerator Replacement	4,368	5,312	944	122%
Education Materials (TLC kits)	2,166	330	(1,836)	15%
Appliance Replacement/Removal*	850	605	(245)	71%
Other	1,660	1,656	(4)	100%
Total**	**75,742**	**41,393**	**(34,349)**	**55%**

*Excluding refrigerator replacement

**Reflects the primary savings associated with each measure. That is, total does not include additional savings generated by some measures, such as the electric furnace fan savings resulting from weatherization or the interactive effects that lighting retrofits have on heating usage for participants that heat with natural gas or delivered fuels.

The following report section (Key Measure-Specific Results) provides more information regarding the four measures - weatherization, lighting, heating systems, and refrigerator replacement – that generate the majority of IES' savings. Additional details regarding all other measures can be found in the evaluation's Supporting Documentation workbook.

Key Measure-Specific Results

This section presents details for key measures within each fuel type.

- **Natural Gas:** Heating Systems and Weatherization
- **Electricity:** Lighting and Refrigerator Replacement
- **Delivered Fuels:** Heating Systems and Weatherization

Natural Gas: Heating Systems and Weatherization

The team used billing analysis to evaluate energy savings for heating system replacement and weatherization in natural gas-heated homes.

The evaluation team conducted a screening process that removed natural gas participants without sufficient billing records or whose bills exhibited extreme or counter-intuitive energy consumption (Table 8). Our billing analysis uses a total of 904 National Grid natural gas-heated households that either received a new heating system or were weatherized through IES. The table below focuses on the treatment group (Program Year 2015–2016 participants), but the evaluation team filtered potential control group customers using similar filters.[7]

Table 8. Billing Analysis Sample Attrition – Natural Gas

Reason for Exclusion	Removed	%	Remaining
All Homes			1,176
Could not be mapped to Billing Data	31	3%	1,145
Insufficient (less than 10 months) Pre- and/or Post-Participation Billing Data	149	13%	996
Energy Consumption Outliers (<1th and >99th Percentile)	24	2%	972
Vacancies (No Billed Consumption for More than 8 Months)	15	1%	957
Extreme Changes in Consumption (±>80% Change between Pre and Post)	17	1%	940
Installed Before February 2015 or After October 2016	36	3%	904
Overall	**272**	**23%**	**904**

[7] See Supporting Documentation workbook for additional details

The team began by specifying a whole-home regression model, where we determine the average energy savings per participant regardless of whether they installed a heating system, were weatherized, or both. After determining average, whole-home savings for this subset of IES participants, the team used the PRR model specification, below, to estimate natural gas savings at a measure level:

$$ADC_{ct} = \sum_{month\ i} b_{1i}Month_{it} + b_2LagADC_{ct} + b_3NonIES_c + \ b_4PostHDD_{ct} \ + \ b_5HeatSys_c * PostHDD_{ct} \\ + \ b_6Wx_c * PostHDD_{ct} + \ e_{ct}$$

Where:

- ADC_{ct} = average, daily energy consumption for customer c at calendar month t
- $Month_{it}$ = 1 when index i = calendar month t, 0 otherwise. We include this series of 12 terms to capture month-specific effects in our analysis.
- $LagADC_{ct}$ = average daily consumption from customer c during calendar month t of the pre-program period
- $nonIES_c$ = 1 if customer c received non-IES measures[8]
- $PostHDD_{ct}$ = average, daily HDD for customer c in calendar month t using a base temperature of 65° F
- $HeatSys_c$ = 1 if customer c received heating system, 0 otherwise
- $Weatherization_c$ = 1 if customer c received weatherization, 0 otherwise
- e_{ct} is the error term from the regression model

The results of the evaluation team's billing analysis of weatherized natural gas-heated IES households follows in Table 9. Using a whole-home model, we determined that the IES participants in natural gas-heated homes averaged 128 therms in savings, or 14% of pre-participation household energy consumption. Heating system replacement and weatherization saved 79 and 124 therms, respectively.

It is important to note that the program did not install many other types of natural gas measures in 2015 and 2016. In fact, other than the heating system replacement and weatherization measures specified in the model, IES only installed a small number (n=36) of domestic hot water measures (i.e., showerheads and aerators) that impacted participants' natural gas usage. As a result, the team was not concerned about the measure-specific regression above associating savings from other gas measures to heating systems and weatherization.

[8] Before arriving at the binary (1 or 0) variable for non-IES participation, the team explored two methods for controlling for the savings associated with non-IES measures. First, the team included the estimated household-level energy savings estimate from the Hancock system, and noted that the regression coefficient was not statistically significant. The team also transformed the Hancock savings estimate into a categorical High/Low/No energy savings variable, which also did not produce a meaningful result.

Table 9. 2015–16 Natural Gas Billing Analysis Results

Measure	Billing Analysis Sample N	Energy Savings (Therms)	Precision* (% +/-)	Normalized Annual Consumption (Therms)	% of NAC
Heating System Replacement	235	79	11%	926	9%
Weatherization	785	124	5%	926	13%
Whole Home	**904****	**128**	**5%**	**926**	**14%**

*The precision above represents the width of the confidence interval. We have used 90% confidence interval in our analysis

**Some customers received both a heating system replacement and weatherization

A comparison of the team's whole home savings with the measure-specific savings—accounting for how many participants received each measure—confirmed the reliability of the team's measure-specific estimates. As shown in Table 10, the participation-weighted measure-specific household savings (127 therms/year) is nearly identical to the whole home model results presented in Table 9 (128 therms/year).

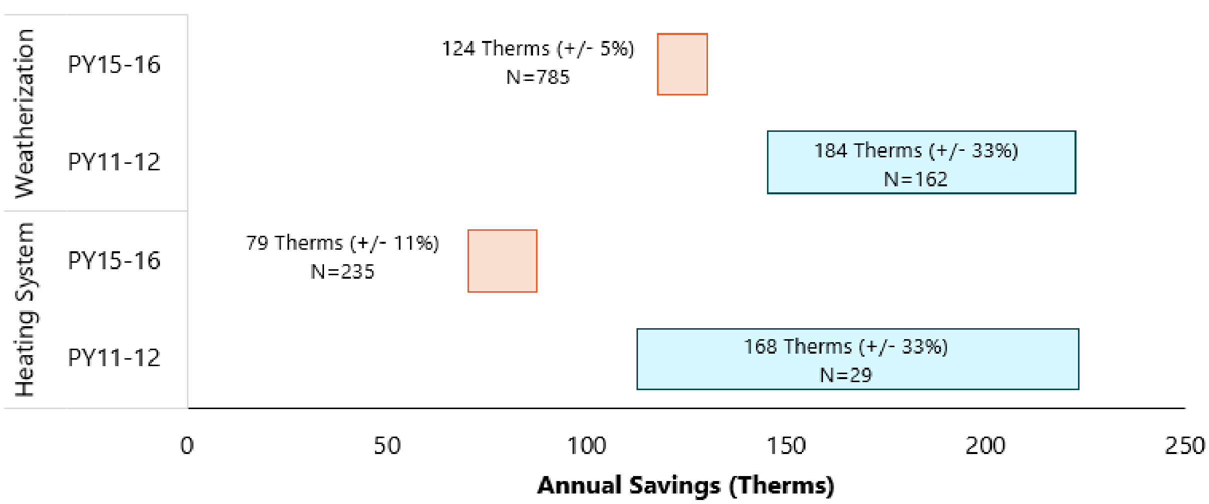
Table 10. Comparison of Whole Home and Measure-Specific 2015–16 Natural Gas Billing Analysis Results

Measure	% Receiving Measure	Energy Savings (Therms)
Heating System Replacement	26%	79
Weatherization	86%	124
Weighted Average Measure-Specific Household Savings		**127**

The evaluation team's analysis yielded ex post savings that are meaningfully and statistically significantly lower than the savings estimated for the same measures through the previous IES impact evaluation, which informed the program's ex ante assumption for these measures. Figure 3 compares the heating system replacement and weatherization savings estimates, as well as the analysis sample sizes and confidence intervals associated with each estimate, from both evaluations. While both evaluations relied on billing analysis to estimate savings, sample sizes and precision estimates for the current evaluation (2015–2016) are much more robust.

Outside of these statistical metrics, the evaluation team did not have access to any information (e.g., changes in average heating system efficiency or insulation r-values) that offered quantitative insight into differences in how IES delivered these measures in 2016 and 2016 relative to the previously evaluated years (2011 and 2012).

Figure 3. Comparison: 2015–2016 and 2011–2012 Billing Analysis Results (Natural Gas)[9]



[9] Note: Previous evaluation adjusts 2011-2012 billing analysis results to derive final savings estimate.

Electricity: Lighting and Refrigerator Replacement

During 2015 and 2016, National Grid Rhode Island IES participants could receive up to four different types of lighting measures through the IES program: compact fluorescent lamps (CFL), EISA-compliant light-emitting diode (LED) lamps, non-EISA compliant LED lamps, and LED reflector lamps. On average, IES participants who received lighting measures received an average of 25.8 bulbs (across all four lighting measures). Due to the high number of lighting measures installed, it was possible for the evaluation team to detect the impact of lighting at the household level through a billing analysis.

Similar to the process used for the natural gas weatherization and heating system replacement measure, the evaluation team conducted a screening process that removed participants with insufficient billing records or whose bills exhibited extreme or counter-intuitive energy consumption (Table 11). At the end of this process, a total of 2,819 treatment group customers remained in our billing analysis sample.

Table 11. Electric Billing Analysis Sample Attrition

Reason for Exclusion	Removed	%	Remaining
All Homes			**4,661**
Could not be mapped to Billing Data	55	1%	4,606
Insufficient (less than 10 months) Pre- and/or Post-Participation Billing Data	1,108	24%	3,498
Energy Consumption Outliers (<1th and >99th Percentile)	86	2%	3,412
Vacancies No Billed Consumption for More than 3 Months	11	0%	3,401
Extreme Changes in Consumption (>80% Change between Pre and Post)	45	1%	3,356
Weatherization or Select Equipment Replacement*	24	1%	3,332
Installed Before February 2015 or After October 2016	513	11%	2,819
Overall	**1,842**	**40%**	**2,819**

*To allow the team to detect lighting savings, the team excluded the small number of electrically heated households that were weatherized through IES, as well as those that received freezer replacement, or appliance removal. Excluding these customers from the billing analysis sample minimized variance and allowed the team to isolate lighting-related savings.

Before arriving at the final model specification below, the evaluation team began by specifying a single PPR model that would produce savings estimates for each of the four lighting measures and for refrigerator replacements—the IES energy-efficiency measures that the team believed would have the largest impact on household electric consumption. However, the team encountered two issues when attempting to quantify savings at this level of resolution. First, the model was unable to estimate statistically significant savings for each the four individual lighting measures (CFL, EISA-compliant LED, non-EISA compliant LED, and LED reflector). Second, due to the high correlation between lighting and refrigerator replacement (over 90% of participants who received refrigerator replacement also received lighting), the model struggled to differentiate between, and assign savings to, each measure.

Ultimately, the team took four actions to obtain a reliable result from our billing analysis model for lighting:

1. Used a single, aggregated variable that indicates whether the customer received any of the four IES lighting types
2. Split lighting and refrigerator replacement into separate models
3. Filtered out any participant that received another IES measure with substantial electric energy savings. Specifically, we:
    - **Both models**: removed weatherized participants (electric-heated homes only), appliance removal, freezer replacement, or air conditioner replacement
    - **Lighting model only**: removed participants that also received refrigerator replacement
    - **Refrigerator replacement model only**: removed participants that also received lighting
4. Limited the terms in the final model specification to only those with statistically significant coefficients. In particular, the team did not include a term for smart strips in the final model specification because it did not have a significant coefficient (i.e., p-value > 0.01).

The decisions above resulted in the team employing the following PPR model specification to estimate electric savings:

$$ADC_{ct} = \sum_{month\ i} b_{1i}Month_{it} + b_2LagADC_{ct} + b_3NonIES_c + b_4Treatment_c + e_{ct}$$

Where:

- ADC_{ct} = average, daily energy consumption for customer c at calendar month t
- $Month_{it}$ = 1 when index i = calendar month t, 0 otherwise. We include this series of 12 terms to capture month-specific effects in our analysis.
- $LagADC_{ct}$ = average daily consumption from customer c during calendar month t of the pre-program period
- $nonIES_c$ = 1 if customer c received non-IES measures[10]
- $Treatment_c$ = 1 if customer c received lighting/refrigerator replacement, 0 otherwise
- e_{ct} is the error term from the regression model

[10] Similar to the natural gas analysis, the evaluation team assessed potential non-IES savings using multiple approaches; none of which produced statistically significant results.

Table 12 shows ex post savings for the IES lighting and refrigerator replacement measures. As shown below, the team estimated that participants who received lighting measures through IES saved, on average, 458 kWh. Since billing analyses are based on a home's total usage, this savings value reflects the household's total lighting-related savings. The team then estimated per-bulb savings (18 kWh/year) by dividing the total savings by 25.8—the average number of bulbs installed in participant's homes.[11]

Table 12. 2015–16 Electric Billing Analysis Results

Measure	Billing Analysis Sample N	Energy Savings (kWh)	Precision (% +/-)	Normalized Annual Consumption (kWh)	% of NAC
Refrigerator Replacement	197	467	25%	6,862	7%
Lighting	985	458	13%	6,707	7%
Whole Home*	**2,819**	**595**	**11%**	**6,838**	**9%**

*Includes customers that installed both lighting and had their refrigerator replaced; these customers were excluded from the refrigerator and lighting-only models.

The team also compared the whole home savings with the measure-specific savings. As shown in Table 13, the weighted sum of refrigerator replacement (63% of participants) and lighting (93% of participants) savings in the 2015–2016 billing analysis sample (720 kwh) is higher than the savings estimate from the evaluation team's whole home model (595 kWh). Ideally, these results are identical; however, because the measure-level billing analysis models used mutually exclusive sets of customers (i.e., separate models for lighting and refrigerator replacement), the difference is not surprising. Also, because the magnitude of the disparity is relatively small (21%), the team did not adjust the measure-level savings estimates to calibrate to the whole-home savings.

Table 13. Comparison of Whole Home and Measure-Specific 2015–16 Electric Billing Analysis Results

Measure	% Receiving Measure	Energy Savings (Therms)
Refrigerator Replacement	63%	467
Lighting	93%	458
Weighted Average Measure-Specific Household Savings		**720**

The evaluation team notes that the savings estimates shown in Table 12 represent something between gross and net energy savings. The precise location of the team's estimate on the spectrum between gross and net energy savings is not knowable given the data that were available during this evaluation—the evaluation scope did not include participant surveys for deriving net-to-gross ratios.

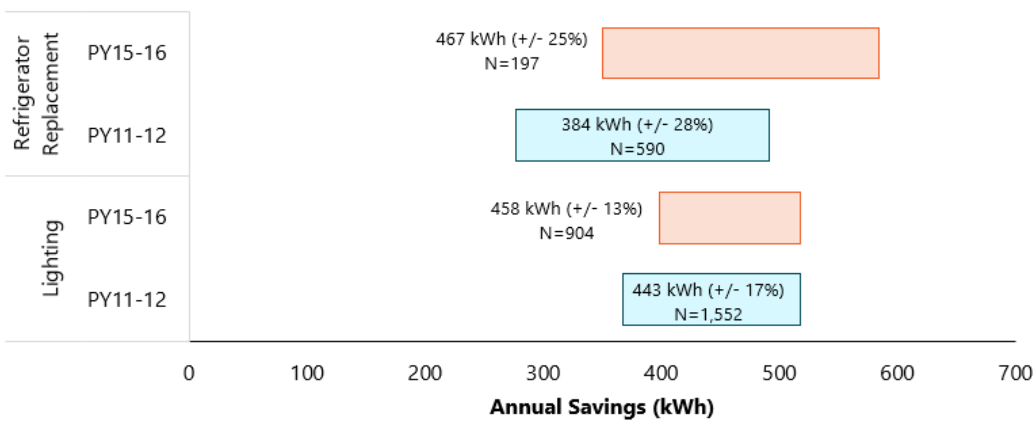
[11] The average number of lamps installed by IES participants included in the lighting-only electric billing analysis (25.8) was almost identical (25.7) to the program's overall average. Therefore, the team did not conduct any subsequent weighting to ensure the sample average was similar to the program average.

However, for lighting measures, which are readily available and relatively affordable, it's possible—even likely—that some customers in our control group of future IES participants installed some number of LEDs themselves prior to participating. If this assertion were true, we assume that our savings estimate is closer to net due to the free-ridership implied by self-funded lighting replacements in the control group.

It is also important to note that the electric billing analysis results above account for any cooling-related impacts (due to post-participation reduced lighting waste heat), as well as heating impacts for the subset of participants that heat with electricity. However, the results do not reflect the impact of IES lighting retrofits on space heating for participants that heat with natural gas or delivered fuels. Future evaluation should consider accounting for these lighting-related interactive effects for these heating fuel types. To enable this analysis as part of future evaluations, IES should track whether lamps are installed in conditioned space.

Similar to the natural gas billing analysis, the evaluation team compared the results and associated confidence intervals determined through the current electric billing analysis to the previous evaluation. The team found the results were not statistically different, although the precision associated with the 2015–2016 result was better for both electric measures.

Figure 4. Comparison: 2015–2016 and 2011–2012 Billing Analysis Results (Electric)



The evaluation team also conducted an additional analysis of lighting savings, segmented by the number of IES bulbs given to each participant. The previous IES evaluation, conducted for program years 2011 and 2012, noted that per-bulb savings decreased as the number of IES bulbs per home increased. Table 14 shows a similar trend, where the homes that received 10 or fewer bulbs through IES saved an average of 82 kWh per bulb, while homes that received more than 40 saved an average of 7 kWh per bulb. While this analysis cannot make any statements about causation (i.e., program bulbs were installed in low-use areas of the home), this finding supports the previous hypothesis of diminishing returns for each incremental bulb.

Table 14. 2015–16 Per-Bulb Savings by Quantity of IES Bulbs Received

Number of Bulbs	Relevant Participants in Billing Analysis Sample N	Per Bulb Energy Savings (kWh)	Precision (% +/-)
1–10	89	82	23%
11–20	416	28	18%
21–30	253	14	25%
31–40	148	19	16%
40 or More	79	7	26%
All	**985**	**18**	**13%**

Delivered Fuels: Heating Systems and Weatherization

Since a billing analysis is not possible for delivered fuels, the evaluation team leveraged the results of natural gas billing analysis to estimate ex post savings for both heating oil and propane heating system replacements.

Applying the evaluation team's natural gas savings to heating oil and propane customers implies similarity between the customers heating with these different fuels. The team assumed that participants who received weatherization and heating system replacements through IES live in similarly sized homes, regardless of heating fuel (natural gas, heating oil, or propane)[12]. Other, implicit similarity assumptions—such as natural gas, heating oil, and propane customers heating their home to similar temperatures in the winter—are not possible to test.

For heating oil, the evaluation team adjusted the total savings determined for weatherized customers heating with natural gas to reflect that heating oil systems are slightly less efficient at converting heating oil into heat. As a result, it takes more heating oil for a customer to heat their home to their desired heating temperature setpoint than it does a natural gas customer. For this reason, the ex post savings associated with weatherized heating oil participants is slightly higher than weatherized natural gas-heated customers (when comparing both savings in similar units, i.e., MMBtus).

For propane, the team directly applied the natural gas savings (converting therms to MMBtu). Propane and natural gas heating systems are comparably efficient when converting their respective fuels into heat. Consequently, it is possible to leverage the natural gas billing result directly.

Table 16 presents ex post savings for both heating oil and propane. Unlike Table 9, which presents the billing analysis-based ex post savings for natural gas heated participants, this summary table does not

[12] Based on audit data from Massachusetts' Home Energy Services program during a concurrent time period (calendar year 2015 and 2016).

include precision estimates; the engineering adjustments and assumptions made for heating oil and propane do not facilitate a measurement of statistical significance.

Table 15. 2015-16 Ex Post Heating System Savings – Heating Oil and Propane

Heating Fuel	Measure	PY15-16 # Participants	Ex Post Savings (MMBTU / Year)
Oil	Heating System Replacement	471	7.8
	Weatherization	670	12.6
Propane	Heating System Replacement	12	7.9
	Weatherization	23	12.4

Recommendations

The evaluation team offers the following recommendations related to the findings of this study, as well as to inform future evaluations.

1. **Use the billing analysis-based lighting savings from this evaluation as prospective savings for future IES program years**. As mentioned previously, National Grid relied on outputs from a residential lighting market adoption model (or MAM) to develop ex ante savings for IES for 2015 and 2016. Using the model for IES is intuitive as the lighting market is experiencing rapid annual change and because other National Grid residential programs rely on the model. However, this evaluation (18 kWh) – like the last IES evaluation (22 kWh) – produced billing analysis-based estimates of per-unit lighting savings much lower than the program's ex ante assumptions, which range from 38.7 to 57.2 kWh depending on the lamp type. Given the large number of lamps installed in the average IES participants' home (25+) and consistent evaluation results showing lower savings through billing analysis, the evaluation team recommends that National Grid use this evaluation's ex post results – and not the MAM – as prospective, ex ante lighting savings for future IES program years. It is important to also note this recommendation may cause a disconnect between the savings IES claims for a specific lamp and the savings claimed for the same lamp by another National Grid program. It is also important to note that the billing analysis results determined through evaluation are likely more reflective of net savings (due to the use of a control group) than gross savings.
2. **Collect and provide future evaluators with more detailed IES data.** Throughout this study, the evaluation team worked closely with National Grid to obtain the most granular program data possible. In most cases, National Grid was able to provide the information the team requested. In some instances, however, additional information that National Grid was unable to provide would have aided the evaluation process. To benefit future evaluations, the team recommends National Grid ensure these additional data fields (which are enumerated in the evaluation's Supporting Documentation workbook) are available to inform future studies.
3. **Monitor changes in measure offerings.** The current evaluation focused its efforts on the measures responsible for the majority of IES' 2015 and 2016 savings. While the team evaluated all measures from these program years, as well as several additional measures that IES has started to offer since 2016 or plans to offer in the future, the bulk of the team's efforts were on evaluating these key and impactful measures. If other measures, such as heat pump water heaters (only one was installed in 2015 and 2016) play a larger role in future program years, the team recommends assigning greater importance to them as part of future ad hoc or full-scale IES evaluations.

Appendix A: Evaluation Workplan

To: Romilee Emerick, National Grid

From: Doug Bruchs, Cadeo

Date: May 25, 2018

Re: IES Impact Evaluation Work Plan

....

This document details Cadeo's plan for completing an impact evaluation of National Grid's 2015 and 2016 Income Eligible Services (IES) program in Rhode Island. This document, which will serve as the work plan for the evaluation, consists of the following sections:

4. Introduction
5. Billing Analysis
6. Engineering Algorithms
7. Building Simulation Modeling
8. Deliverables and Schedule
9. Evaluation Team
10. Project Management
11. Data Request

Introduction

National Grid established three objectives for the 2015 and 2016 IES impact evaluation:

1. Estimate the overall average energy savings attributable to the IES program
2. Provide credible energy savings and realization rates for each electric, natural gas, propane and heating oil measures and/or measure groups
3. Report findings and observations and provide recommendations on program design to help improve the effectiveness of the program

As outlined in our proposal, our team will meet these three objectives using a combination of billing analysis, technical reference manual-based (TRM) engineering algorithms and building simulation modeling. We believe these complementary evaluation approaches will yield the credible measure-specific savings National Grid seeks and offer insight National Grid can use to inform IES program planning in 2019 and beyond.

At this point in time, we cannot definitively state which approach our team will use to evaluate each specific IES measure. Whenever possible, our preference is to rely on billing analysis. This is because billing analysis, using a well-matched control group and informed by robust program data, best reflects the actual change in energy usage within participating homes. However, billing analysis is not a viable option for all IES measures; the per-measure savings expected from many IES measures is not large enough to detect via billing analysis given the level of program participation in 2015 and 2016. In addition, it is challenging for billing analysis to accurately attribute overall observed savings to specific measures when many measures are installed simultaneously, especially when the sets of measures received by participants is similar.

Currently, we anticipate using the approach listed in Table 16 to report savings for each IES measure. However, the actual approach our team uses may change after we review the program and billing data requested at the end of this workbook.

Table 16. Anticipated Impact Methodology by IES Measure and Fuel*

	Electric	Natural Gas	Heating Oil	Propane
AC Replace	Algorithm	N/A	N/A	N/A
AC Timer	Algorithm	N/A	N/A	N/A
Appliance removal	Algorithm	N/A	N/A	N/A
CFL	Billing Analysis	N/A	N/A	N/A
Clothes Washer and Dryer**	Algorithm	N/A	N/A	N/A
Dehumidifier**	Algorithm	N/A	N/A	N/A
Domestic Hot water	Algorithm	Algorithm	Algorithm	N/A
Education materials	Algorithm	N/A	N/A	N/A
Freezer	Algorithm[#]	N/A	N/A	N/A
Heat Pump Water Heaters	Simulation	N/A	N/A	N/A
Heating Systems, Boiler	N/A	Billing Analysis	Simulation	Simulation
Heating Systems, Furnace	Simulation (Fan)	Billing Analysis	Simulation	Simulation
LED Bulbs	Billing Analysis^	N/A	N/A	N/A
LED EISA EXEMPT	Billing Analysis^	N/A	N/A	N/A
LED Reflectors	Algorithm	N/A	N/A	N/A
Programmable Thermostat	N/A	Algorithm	Algorithm	Algorithm
Refrigerator rebate	Algorithm[#]	N/A	N/A	N/A
Showerhead	Algorithm	Algorithm	Algorithm	Algorithm
Smart Strip	Algorithm	N/A	N/A	N/A
Waterbed	Algorithm	N/A	N/A	N/A
Weatherization	Simulation	Billing Analysis	Algorithm	Algorithm

*The team listed measure/fuel combinations as "N/A" if National Grid did not report savings for the measure and fuel type in Table 1 or 2 in the IES impact evaluation RFP. The team anticipates reviewing this list of measures and fuel types, and updating as necessary, as part of the evaluation's kick-off meeting.

**New measures added for 2017 and 2018, not part of the 2015 and 2016 program years being evaluated.

^The previous IES impact evaluation used an engineering approach to estimate savings for LEDs since, at the time, LEDs were relatively new to IES and not installed in sufficient numbers to support billing analysis.

[#]The previous IES impact evaluation used billing analysis to estimate savings for appliance rebates. However, the precision associated with these estimates were not robust.

In most cases, our team will rely exclusively on the approach identified in Table 17. However, for certain measures and fuel type combinations, the team will employ multiple approaches to generate the most reliable savings estimate and/or gain additional insight into program design and delivery. These measure and fuel combinations include:

- **Weatherization and Heating Systems (Heating Oil and Propane).** The team expects our billing analysis of natural gas weatherization and heating systems to result in statistically significant savings (confidence and relative precision of 90/10 and 90/15, respectively). Since a comparable billing analysis is not possible for these delivered fuels, the team will leverage the billing analysis-based results for natural gas to calculate weatherization and heating system savings for heating oil and propane. Specifically, the team will use engineering calculations to account for differences in the average heating system efficiencies across fuels and, if necessary, adjust for any known differences in the size of natural gas heated participants' home relative to participants heating with oil and propane.
- **Lighting Measures.** The team will estimate CFL and LED savings using the algorithm specified in the Rhode Island TRM, as well as using billing analysis. Sometimes the team uses multiple methods to better estimate savings. In other instances, such as with these screw-in lighting measures, our team uses a secondary method to gain insight into program delivery. In the case of lighting, our team's previous work in New England has found that billing analysis can reveal meaningful differences in per-bulb savings depending on the total number of bulbs installed in a given home. This information can provide insight into the optimal number of bulbs to install as part of future program cycles.

The following three sections offer more details about the specific methodology our team will use for each of the three impact evaluation approaches identified in Table 17.

Billing Analysis

To generate more robust savings estimates, the team plans to combine 2015 and 2016 participants into a pooled model and estimate average savings across both years (versus estimating separate savings for each year). At this time, our team is not aware of any changes in IES delivery between 2015 and 2016 that would suggest that aggregating participants across years for evaluation purposes inappropriate. Our team will confirm this understanding at the evaluation's kick-off meeting. For the remainder of this work plan, we refer to this aggregated group of 2015 and 2016 IES participants as the treatment group.

Our team will use a monthly Post Program Regression (PPR) model to estimate average measure-specific savings for the measure and fuels shown in Table 17. The general form of a Post Program follows[13]:

$$\mathrm{ADC_{ct}} = \mathrm{b_1 Treatment_c} + \mathrm{b_2 LagADC_{ct}} + \sum_{\mathrm{month\ i}} \mathrm{b_{3i} Month_{it}} + \sum_{\mathrm{month\ i}} \mathrm{b_{4i} Month_{it} {*} LagADC_{ci}} + \mathrm{e_{ct}}$$

Where

12. ADC_{ct} = average, daily energy consumption for customer *c* at calendar month *t*
13. $Treatment_c$ = 1 if customer c is in treatment group, 0 if customer c is in control group.
14. $LagADC_{ct}$ = average daily consumption from customer *c* during calendar month t of the pre-program period

---

[13] If we need to estimate savings for more than one weather-sensitive or base load measure, we add the appropriate terms for each measure.

15. $Month_{it}$ = 1 when index i = calendar month t, 0 otherwise. We include this series of 12 terms to capture month-specific effects in our analysis.
16. e_{ct} is the error term from the regression model.

In the model above, we derive annual, measure level savings from the coefficient b_1, which represents the average daily savings (kWh for electric, therms for natural gas) due to the program. As we learn more about the IES program data that are available and wrap up our concurrent work with the Home Energy Services evaluation in Massachusetts, we will make a final decision about the model specification. We will communicate and vet the final model specification with the IES evaluation stakeholder group via the analysis plan our team will distribute in mid-June.

In the model above, in addition to the treatment group customers, we also use a set of control group customers to account for the impact of various macroeconomic factors and other influences on pre- and post-program energy consumption that are unrelated to the installation of program measures. These factors include, but are not limited to, macroeconomic trends, the movement of people in and out of homes, and fluctuations in per-unit energy costs.

It's critical that the control group be as similar, in terms of both the customer profiles and energy usage, to the treatment group as possible. Our team will ensure comparability between the treatment and control group in two ways.

1. **Making use of "future" IES participants.** Consistent with our team's previous evaluations for National Grid in Massachusetts, we will use the set of customers that participated in IES in 2017 for our control group. Since these customers also participated in IES, we can assume that they are similar (in terms of housing stock, income eligibility, and consumption habits) and therefore offer a reasonable counterfactual for participants in 2015 and 2016. Although these specific customers later received measures through IES, our team will only make use of their energy consumption data prior to that time.
2. **Matched pre-program energy consumption.** To identify the most relevant 2017 IES participants for the control group, we will use the quasi-experimental matched control group (MCG) method. The MCG method matches each participant in the treatment group (i.e., a 2015 or 2016 IES participant) with a specific "best match" from a pool of potential control group customers (i.e., a 2017 IES participant) based on pre-program energy usage. The team's MCG approach will use a nearest-neighbor algorithm to match each treatment customer to a specific control group customer. In other words, the MCG approach results in a one-to-one match between a specific treatment and a specific control group customer based on both customers' energy consumption pattern over the 12 pre-participation months prior to the treatment customer's participation in IES. The MCG approach does allow for one-to-many mapping, that is, a customer in the control group can potentially be the "best match" for more than one customer in the treatment group. Given the number of customers that participate in IES each year, it is likely this will occur as part of our team's matching process. Our team will also explore alternative control group approaches such as a matching approach that would allow our team to map more than one many customers in the control group to each treatment group customer.

In our proposal, we raised another issue related to accurate billing analysis: the conflation of savings generated by IES measures and measures installed by participating Community Action Agencies (CAAs) using non-National Grid funding. Identifying the specific savings attributable to National Grid is possible if our team has access to complete and robust information about both National Grid and non-National Grid measures installed in IES customers' home. According to our early discussions with National Grid, we anticipate such data will be available for our analysis. If not, the team will need to revisit the approach outlined in this work plan. Assuming such information is available, we will include a variable in our model that controls for the savings generated by measures not funded by National Grid.

Some of the improvements made using non-National Grid funding are made to improve the health and safety of a customer's home. In some cases, these improvements can impact the energy consumption of the customer's home. Once our team reviews the available IES and non-IES measure data, we will make a determination about how we will account for these non-energy efficiency health and safety improvements.

In addition to using the billing analysis to provide National Grid with measure-specific savings for a subset of IES measures, our team will also use the billing analysis to estimate total average household savings. This customer-level level assessment of IES' savings captures the program's total impact on participating homes. It also provides an important quality assurance check when combining measure-specific savings from different methodologies. Specifically, it's important that the sum of the various measure-specific savings associated with the average customer are in-line with the total household savings. If not, it's possible a specific methodology is over or underestimating actual savings or that the evaluation is not sufficiently accounting for the interactive effects generated by IES' measures.

Engineering Algorithms

Concurrent with the billing analysis described above, our team will estimate savings using technical reference manual-based engineering algorithms, available IES tracking data, and the most relevant secondary data sources.

The engineering analysis will, in general, build on the RI TRM algorithms and savings estimates to update and improve certain inputs in developing ex post savings estimates. The research team will rely, primarily on detailed and program-specific audit information that provides the best estimate of savings for the specific population of program participants being evaluated. Where detailed primary data is not available or is insufficient, the team will review and develop secondary sources for certain inputs from other existing studies, literature, or data sources. Much of these secondary sources already exist in the Massachusetts LI or HES evaluation workbooks or are known to the research team based on previous work. As such, the research team anticipates being able to generate reliable and robust estimates for ex post inputs based on available primary or secondary data. In certain cases, the research team may need to rely on ex ante estimates or other assumptions developed in collaboration with the National Grid team.

In addition to generating reliable and precise savings estimates based on the best available data, such a detailed algorithm-based approach will allow the research team to disaggregate savings estimates for each measure into their component parts to understand the contributions of the primary measure and any measure interactions.

As noted in our proposal, the team will start with engineering algorithm workbooks that Cadeo created as part of the ongoing HES impact evaluation in Massachusetts for time, cost, and consistency reasons. These workbooks are an ideal starting point since we developed them for National Grid and many of the more than two dozen IES measures are also part of National Grid's HES initiative in Massachusetts.

The EXCEL workbook will contain a tab for each IES measure. Each measure-specific tab in the workbook will include:

- The savings algorithm from the RI TRM
- A list of all inputs and input values, includes detailed source information
- A clear comparison of the TRM and evaluation inputs
- Calculation of savings according to the algorithm specified in the TRM
- A succinct explanation for why any assumptions or inputs differ from the TRM and impact the realized savings

These tabs allow for an easy way to understand the basis of each savings estimate, as well as the source of any differences between the ex ante and ex post estimates. In addition to these measure-specific tabs, the workbook will also include a centralized tab for inputs and assumptions that are common across measures. Maintaining these values (and the relevant sources) in a centralized location ensures that an update to a common input impacts all affected measures (i.e., preserving internal consistency). Setting up the workbook this way will also facilitate planning and lower the cost of future evaluation updates.

Building Simulation

For IES measures known to generate (or be subject to) interactive effects or that do not readily lend themselves to engineering algorithms or billing analysis, we plan to estimate average, measure-specific energy savings using building simulation modeling. Specifically, the team will use BEopt, modeling software created by the National Renewable Energy Laboratory that utilizes the Department of Energy's EnergyPlus as its simulation engine. As with the other aspects of our work plan, this approach and modeling software is consistent with our team's current evaluations for National Grid in Massachusetts and leverages previous models that were developed for the Massachusetts HES evaluation.

However, in this case, the team will generate a series of simulations that are representative of the population of National Grid IES participants. We will determine the exact number of scenarios that we will simulate following our review of program data. Currently, we expect to model at least 2 prototype buildings: one reflecting participants living in single-family detached homes and one for participates in multi-unit residences. The team will develop unique building simulation results for each specific fuel type. For each fuel type, we will develop simulations that are as representative of the specific program participants and fuel-specific housing characteristics.

To do this, Cadeo will rely on detailed program participant information to develop building simulation inputs, consistent with the engineering analysis. That is, we plan to use the program, dwelling, and demographic data gathered as part of the previous task to create models that are Rhode Island- and IES-specific. Should the National Grid, CLEAResult, or the community action agencies be unable to provide a critical data element, our team will work with National Grid to identify the best possible secondary source (e.g., Rhode Island-specific Census data).

In addition, to ensure accurate results and consistency with the billing analysis, Cadeo will calibrate each simulation model using participant energy consumption data. Specifically, we will calibrate the models based on the average total pre-program energy consumption and average heating-related energy consumption. These efforts will ensure that the building simulation is as consistent as possible with the billing analysis and engineering analysis.

If National Grid is interested in assessing the relative savings associated with the various components of its weatherization jobs (i.e., air sealing and different insulation types, such as attic, wall, and basement), our team can also leverage the building simulation to disaggregated the overall billing analysis result into these constituent elements.

Deliverables and Schedule

The three impact evaluation methodologies detailed above will result in numerous draft and final deliverables. Table 17 lists these deliverables and the date our team will submit each to National Grid.

Our team anticipates revisiting the schedule below as part of the kick-off meeting and, if necessary, making updates to meet National Grid's reporting needs and expectations. We will document the official schedule in the final work plan. Until then, reviewers should consider the deliverable dates below as tentative.

Table 17. Tentative Evaluation Deliverables and Schedule

Deliverable/Event	Date	Notes
Data Request (**Submitted**)	April 26th	
Work Plan (**Draft**)	May 1st	
Kick-Off Meeting	May 14th	
Data Request (**Fulfilled**)	May 18th	
Work Plan (**Final**)	May 23rd	
Data Review Memo	June 8th	
Analysis Plan Memo (**Draft**)	June 15th	
Analysis Plan Memo (**Final**)	June 29th	Assumes one week for National Grid and stakeholder review, followed by one week for the evaluation team to make final changes
Preliminary Results Presentation	Week of July 16th	
Evaluation Report, including engineering algorithm workbooks (**Draft**)	July 27th	
Evaluation Report, including updated engineering algorithm workbooks (**Revised**)	August 10th	Assumes one week for National Grid and stakeholder review, followed by one week for the evaluation team to make revisions.
Evaluation Report, including engineering algorithm workbooks and copies of all building simulation files (**Final**)	August 24th	Assumes one week for National Grid and stakeholder review, followed by one week for the evaluation team to make final changes.

It is also imperative to note that the timeline in Table 18 is contingent on the timely delivery of program and billing data. If National Grid provides these data later than specified in the table, our team will adjust the deadlines associated with each deliverable above accordingly.

Evaluation Team

Our evaluation team is unchanged from our proposal, which we created to form a small number of dedicated staff members to quickly and cost-effectively complete the IES evaluation. Our entire team is actively working, in nearly identical roles, on Cadeo's evaluation of National Grid's HES initiative in Massachusetts. Since the HES evaluation is nearly finished, our entire team will be available to transition directly to the IES evaluation.

Figure 5. Evaluation Team

Each team member will have a specific role and set of responsibilities:

- **Doug Bruchs** will be the project manager and serve as National Grid's day-to-day contact. In addition to keeping the evaluation on schedule and budget, Doug will share his experience working with National Grid specifically, and in Massachusetts more generally, with the team to make sure the team's work products are consistent with past and ongoing evaluations.
- **Dr. Sarah Widder** will be the technical lead for both the building simulation and engineering algorithm tasks. She's serving in a similar role on the current HES impact evaluation in Massachusetts and will bring that experience, as well as her time as a Principal Investigator at Pacific Northwest National Laboratory, to bear on this project.
- **Jonah Hessels** is an Massachusetts Institute of Technology engineer. He's currently creating Cadeo's algorithm workbook and building simulation models for the HES evaluation in Massachusetts. His familiarity with those resources will allow him to accurately and efficiently update them to reflect IES and Rhode Island's TRM.
- **Fred Schaefer** leads Cadeo's team of quantitative consultants and will advise on the billing analysis task. He's worked closely with CLEAResult data and led many billing analyses.
- **Bilsay Varcin,** will conduct the billing analysis and any associated data preparation activities. He, like the rest of our team, has worked on the HES impact evaluation in Massachusetts.

Project Management

The team recommends scheduling a half hour to one-hour recurring project management call every two weeks between Doug Bruchs, our project manager, and Romilee Emerick, National Grid's evaluation manager. These meetings will allow our team to provide informal updates on our progress, as well as triage any issues that arise during the evaluation in a timely fashion.

Per National Grid's request, our team will also submit an official status report each month, along with our invoice, by the first Tuesday of every month. The status reports will summarize our recent accomplishments, outlined the activities our team will undertake next, and offer updates regarding the evaluation's schedule and budget.

Data Request

This memo also includes the data request Cadeo previously submitted to support this evaluation. Our data request includes two components – program data and billing data – each detailed below.

Program Data

Our analysis approach can accommodate a wide variety of data structures and formats. Consequently, we ask that National Grid provide our team with the most granular program data available for IES participants in 2015 and 2016.

While flexibility exists, we ask that the data include – at a minimum – the following information:

- National Grid Account Number
- 17. Customer ZIP code
- Owner/Renter Indicator
- Audit Date
- Primary Heating Fuel Type (e.g., natural gas, electricity, heating oil, propane, other)
- Any information about the home, including
    - Type (e.g., single family detached, 2-4 units
    - Number of Stories (single or multi-story)
    - Size (square footage)
    - Relevant information regarding the existing conditions in the home prior to participation (e.g., existing attic insulation R-value prior weatherization)
- Information regarding all measures installed using National Grid funds, including:
    - Quantity and efficiency level (e.g., the amount of insulation, in terms of square footage and change in R-value, added in a weatherized attic)
    - Measure-specific installation date
    - Measure-specific estimated (also known as ex ante) savings

Please also provide similar information – whether part of the same dataset or via a separate – for any energy efficiency measures installed in IES participating homes using non-National Grid funding. If provided separately, include the participant's account number so our team can combine this information with National Grid funded measure installations.

In addition, please provide a list of the customers that participated in IES in 2017 and 2018, as well as the date of each customer's initial audit. We do not need any additional information about the specific measures these customers installed through IES. (We will use these "future" participants as the control group in our billing analysis so less detail is sufficient.)

Billing Data

Please provide the following fields for all customers that participated in IES in either 2015, 2016 and 2017. If National Grid does not currently have a list of these customers, our team can develop and provide such a list after receiving the program data requested above.

Since our billing analysis requires a year's worth of pre- and post-participation energy consumption records, please provide the billing data for the customer's identified above from January 1st, 2014 through December 31, 2017.

At a minimum, we need the following fields:

- National Grid Account Number
- Customer ZIP code
- Billing period dates: start date and end date
- Billing period consumption (kWh consumed for electric, therms consumed for gas)

Regarding format for billing data, if possible, please provide the data as a SAS dataset (sas7dbat file). If not possible, please provide the data in a pipe ("|") delimited text file.

valuation\Work Plan and Data Request\NG RI - IES Impact Evaluation Work Plan_FINAL_25MAY2018.docx

Appendix B: Data Review and Analysis Plan

To: Romilee Emerick, National Grid

From: Doug Bruchs, Cadeo

Date: July 20, 2018

Re: IES Impact Evaluation Data Review and Analysis Plan

....

This document summarizes Cadeo's review of the data provided by National Grid in support of our ongoing impact evaluation of the 2015 and 2016 Income Eligible Services (IES) program in Rhode Island. Based on our review of the available data, we have developed the analysis plan outlined in this document, which expands upon the higher-level evaluation proposal communicated in our team's May 25th work plan.

This document consists of the following sections:

18. Data Sources
19. Results of Data Review
20. Billing Analysis Details
21. Engineering Algorithms Details
22. Building Simulation Modeling Details
23. Updated Deliverables and Schedule

Data Sources

To date, National Grid has provided our team with the following datasets:

- **IES Measure Data**. Included basic customer (account number, ZIP code, heating fuel type) and measure (measure type, quantity, savings) information for 2015, 2016, and 2017 participants (the latter of which we will use as a control group in the billing analysis).
- **Supplemental Participant Data**. Provided additional information regarding the number of units in participating buildings, as well as the type (central or room), size (number of BTUs), and number of cooling systems present in participating customers' homes.
- **Non-IES Measure Data.** Contained information regarding the energy efficiency measures, as well as health and safety improvements, made in IES customer homes that were not funded by National Grid. These measures and/or improvements were funded by one of the following sources: Department of Energy Weatherization Assistance Program (DOE WAP) or Health & Human Service Weatherization Assistance Program (HHS WAP).
- **Billing Data**. Provided energy consumption data for customers between January 2014 to April 2018. The raw dataset includes energy usage of both program participants and program future participants, along with other variables such as billing cycle dates, customer type, and billing rate type.

Apart from data above, we acquired weather data from NOAA (National Oceanic and Atmospheric Administration) weather stations based on ZIP code locations:

- **NOAA Weather Data**. Weather data for each National Grid customer was developed using the weather station closest to the customer's zip code. This allowed for each customer's heating and cooling degree days used in the analysis to be specific to the area for which their billing data is associated. Providence, Block Island[14], and North Central State Airport weather stations were used for this analysis.

Results of Data Review

We began our review by assessing the IES measure data, which will underly all aspects of our evaluation. Specifically, we assessed the number of unique participants provided (9,980), total measure installations (61,989), and range of IES participation (2015–early 2018).

Table 19 summarizes our findings and compares them to the measure participation rates National Grid included in its request for proposal. As evident below, our analysis of the IES measure data did not match National Grid's reported value but exhibited a similar magnitude of participation for key impact evaluation measures such as LEDs, heating systems, and weatherization.

Does it matter that these counts do not match?

Ideally our analysis of the provided data would match National Grid's reporting exactly. However, since National Grid has charged our team with developing measure-specific ex post savings—not calculating total IES savings (i.e., per measure savings multiplied by participation counts in 2015 and 2016) — it is not imperative that our participation counts match National Grid's.

[14] The Block Island weather station is not in National Grid's service territory, but it is the closest weather station to some IES participants.

Table 18. 2015–16 IES Participation Comparison: RFP vs. Provided Program Data*

	RFP				Program Data			
	Electric	**Natural Gas**	**Oil**	**Other**	**Electric**	**Natural Gas**	**Oil**	**Other**
AC Replacement (Window Unit)	925	N/A	N/A	N/A	862	N/A	N/A	N/A
AC Timer	196	N/A	N/A	N/A	196	N/A	N/A	N/A
Appliance removal	16	N/A	N/A	N/A	17	N/A	N/A	N/A
CFL	21,846	N/A	N/A	N/A	21,825	N/A	N/A	N/A
Clothes Washer and Dryer**	-	N/A			-	N/A		
Dehumidifier**	-	N/A	N/A	N/A	-	N/A	N/A	N/A
Domestic Hot Water (Aerators or Showerheads)	13	36	4	-	10	36	4	-
Education Materials (TLC kits)	4,603	N/A	N/A	N/A	4,597	N/A	N/A	N/A
Freeze Replacement	285				286			
Heat Pump Water Heaters	1	N/A	N/A	N/A	-	N/A	N/A	N/A
Heating Systems	-	362	241	5		362	471	12
LED Bulbs	77,183	N/A	N/A	N/A	86,037	N/A	N/A	N/A
LED EISA EXEMPT	11,147	N/A	N/A	N/A	2,389	N/A	N/A	N/A
LED Reflectors	5,082	N/A	N/A	N/A	5,085	N/A	N/A	N/A
Programmable Thermostats**	-	-	-	-	-	-	-	-
Refrigerator Replacement	3,336	N/A	N/A	N/A	3,329	N/A	N/A	N/A
Smart Strip	6,264	N/A	N/A	N/A	6,265	N/A	N/A	N/A
Waterbed	3	N/A	N/A	N/A	3	N/A	N/A	N/A
Weatherization	48	846		693	46	1,018	670	23

* The team anticipated some discrepancies between the RFP participation totals and the provided IES data due to potential differences in reporting (e.g., using payment vs installation data).

**Added in 2017/2018 or under consideration for future inclusion; not offered as part of IES during 2015 and 2016 program years.

The measure-specific participation counts in the provided IES measure data are important for determining which evaluation approach—billing analysis, engineering algorithm, or building simulation—our team will use to estimate ex post savings for each measure.

As stated in our work plan, our preference is to rely on billing analysis when possible. We believe billing analysis (when employing a well-matched control group) best reflects the actual change in energy usage within participating homes. However, as also noted in the work plan, billing analysis is not a viable option for all IES measures. Measures are not appropriate for billing analysis for two common reasons: 1) the anticipated per-measure savings for that measure is not large enough to detect via billing analysis, and/or 2) too few 2015 and 2016 participants received the measure.

Based on the participation rates shown in Table 19, above, our team revisited our proposed evaluation approach for each measure in the work plan. In general, the similarity between the provided IES measure data and the RFP measure-specific reporting confirmed our proposed approach is viable.

Table 19. Updated Impact Methodology by IES Measure and Fuel*

	Electric	Natural Gas	Heating Oil	Propane
AC Replacement (Window Unit)	Algorithm	N/A	N/A	N/A
AC Timer	Algorithm	N/A	N/A	N/A
Appliance removal	Algorithm	N/A	N/A	N/A
CFL	Billing Analysis	N/A	N/A	N/A
Clothes Washer and Dryer**	Algorithm	N/A	N/A	N/A
Dehumidifier**	Algorithm	N/A	N/A	N/A
Domestic Hot Water (Aerators or Showerheads)	Algorithm	Algorithm	Algorithm	N/A
Education Materials (TLC kits)	Algorithm	N/A	N/A	N/A
Freezer Replacement	Algorithm	N/A	N/A	N/A
Heat Pump Water Heaters	Simulation	N/A	N/A	N/A
Heating Systems***,#	Algorithm	Billing Analysis	Algorithm	Algorithm
LED Bulbs	Billing Analysis	N/A	N/A	N/A
LED EISA EXEMPT	Billing Analysis	N/A	N/A	N/A
LED Reflectors	Billing Analysis	N/A	N/A	N/A
Programmable Thermostats**	N/A	Algorithm	Algorithm	Algorithm
Refrigerator Replacement	Billing Analysis	N/A	N/A	N/A
Smart Strip	Algorithm	N/A	N/A	N/A
Waterbed	Algorithm	N/A	N/A	N/A
Weatherization#	Algorithm	Billing Analysis	Algorithm	Algorithm

*The team listed measure/fuel combinations as "N/A" if National Grid did not report savings for the measure and fuel type in Table 1 or 2 in the IES impact evaluation RFP. The team anticipates reviewing this list of measures and fuel types, and updating as necessary, as part of the evaluation's kick-off meeting.

**Added in 2017/2018 or under consideration for future inclusion; not offered as part of IES during 2015 or 2016 program years.

***The work plan included separate line items for furnaces and boilers.

#Team will also use building simulation to estimate heating system fan and/or air conditioning savings

In most cases, our team will rely exclusively on the approach identified in Table 20. However, for certain measures and fuel type combinations, the team will employ multiple approaches to generate the most reliable savings estimate and/or gain additional insight into program design and delivery. These measure and fuel combinations include:

- **Weatherization and Heating Systems (Heating Oil and Propane).** Since a billing analysis is not possible for these delivered fuels, our team will leverage the billing analysis-based results for natural gas customer to evaluate weatherization and heating system savings for heating oil and propane customers. Specifically, we will apply the observed percentage of total heating consumption saved by natural gas participants as determined through the billing analysis to IES customers who heat with a delivered fuel. In doing so, the team will use engineering calculations to account for differences in the average heating system efficiencies across fuels and, if necessary, adjust for any known differences in the size of natural gas heated participants' homes relative to participants heating with oil or propane.
- **Lighting Measures, Smart Strips, and Refrigerators.** The team will assess several electric measures (lighting, smart strips, and refrigerator removal and replacement) using both billing analysis and engineering algorithms.[15] The team will officially report ex post savings using billing analysis, if that method yields reliable, statistically-significant results. If not, the team will report savings using the algorithms listed in the Rhode Island TRM. Regardless of the reporting approach the team uses, these complementary approaches will yield insight into program delivery for lighting. As evident in the previous IES evaluation, billing analysis can reveal meaningful differences in per-bulb savings depending on the total number of bulbs installed in a given home. This information can provide insight into the optimal number of bulbs to install in future program cycles.

Billing Analysis Details

This section describes our billing analysis process in detail.

- Applicable Measures
- Treatment Group Selection
- Control Group Selection
- Data Preparation
- Model Specification

Applicable Measures

As shown in Table 20, our team will use billing analysis to estimate savings for the following electric and gas measures. We anticipate the billing analysis will produce statistically significant results for these measures, which we have defined as results with greater than 20% precision at 90% confidence.

- **Electric**. CFLs, LEDs (general service, EISA EXEMPT, and reflectors), Refrigerator Replacement, and Smart Strips
- **Natural Gas.** Heating Systems and Weatherization

[15] While a similar measure, the number of freezer participants is likely too low to yield statistically viable results.

To ensure robust results, our team will use engineering algorithms to assess savings for each of the identified electric measures. We will compare the algorithmically derived results to the billing analysis results to validate their reliability.

Also, it is likely that the billing analysis will not produce statistically significant savings for each of the specific IES lighting measures listed above (CFLs, LEDs (general service, EISA EXEMPT, and reflectors). In this event, the team will aggregate these individual lighting measures and model savings for the group. This aggregation approach works well since billing analyses occurs at the household level anyway—making it difficult to differentiate savings between very similar measures.

Treatment Group Selection

For our electric and natural gas billing analyses, we define treatment groups as those customers who satisfy the measure installation criteria shown in Table 21.

Table 20. Billing Analysis Treatment Group Details

Savings Fuel	Measures	Installation Period
Electric	CFLs LEDs (All Types) Refrigerator Replacement Smart Strips	January 1, 2015 through October 31, 2016*
Natural Gas	Weatherization Heating System Replacement	February 1, 2015** through October 31, 2016

*We restrict the treatment groups to those IES customers who had measures installed by October 31, 2016 to ensure that each matched control customer has 12 months of data after the treatment customer's installation date.
** The gas measures included in the billing analysis are not direct-install; we assume a blackout period around the measure install date that does not allow January 2015 participants to have a full 12 months of pre-installation billing data.

Discussions at the kick-off meeting confirmed that no significant changes in IES delivery occurred between 2015 and 2016 that would render aggregating participants across years for evaluation purposes inappropriate. For the remainder of this analysis plan, we refer to the aggregated group of 2015 and 2016 IES participants as the treatment group.

Control Group Selection

In addition to the treatment group customers described above, we also use a set of control group customers to account for the impact of macroeconomic factors and other influences on pre- and post-program energy consumption that are unrelated to the installation of program measures. These factors include, but are not limited to, macroeconomic trends, the movement of people in and out of homes, and fluctuations in per-unit energy costs. For this analysis, we define our control group as the 3,547 IES participants from 2017 and early 2018 (Table 22). None of these customers also received measures in 2015 and 2016. It's important to note that, though these participants later received measures through IES, we will only make use of their energy consumption data prior to participation.

Table 21. Billing Analysis Control Group Details

Savings Fuel	Measures	Installation Period
Electric	Any IES Measure	January 1, 2017 through December 31, 2017
Natural Gas	Any IES Measure	January 1, 2017 through December 31, 2017

Creation of Pre- and Post-Periods

As mentioned above, the treatment group are customers who have installed at least one IES measures between 2015 and 2016. However, since treatment participation period is two years long and customers IES measures at various times, we will determine customer-specific pre and post periods. For each customer, the day before the earliest IES installation date (usually the date of the audit when direct install measures such as lighting and aerators are installed) is the latest day of pre-period. Conversely, the day after each customer's last installation date marks the first day if post period. We will not include customers' energy consumption between pre and post period in billing analysis. To further ensure a clear demarcation between the pre and post periods, we will use one month before pre-period, as well as one month after post-period as a holdout month. Since billing cycles do not perfectly align with monthly cycles, using a holdout month will ensure we have a clearly defined pre and post periods. Table 23 below tables provides an example of pre- and post- periods for a specific customer.

Table 22. Example of Pre-Post Period Determination

First Installation	12-month Pre-Period	Latest Installation	12-month Post-Period
February 8, 2015	January 2014 – December 2014	May 28, 2015	July 2015 – June 2016

Data Preparation

Before specifying the billing analysis models, we will conduct two data preparation steps:

- Weather Normalization
- Billing Data Screening
- Matched Control Group Selection

Weather Normalization

After mapping customers to the closest weather station, we will obtain daily temperature data for the period that matches the billing data period and calculate daily HDDs and CDDs using 65ºF as the base temperature. We calculate average daily degree days for the exact days in each billing cycle in the billing data.

Billing Data Screening

After identifying the treatment and control group customers, we will apply a set of billing data screening criteria to ensure that our billing analysis model uses clean and accurate consumption data for each time interval. We will exclude customers who meet one or more of the following criteria from our analysis:

- Unable to link billing data to program participation data

- Insufficient pre- or post-billing data (i.e., less than nine months of pre or post months)
- Billed consumption does not meet reasonable monthly values (outlier removal, i.e. remove 1st and 99th percentile)
- Large changes in pre- to post- installation period energy consumption (i.e., +/- 80%)

Matched Control Group Selection

After conducting the data screening process described above, we match each treatment group customer to a "future" (2017 and 2018) IES participants to develop a control group similar, in terms of both the customer profiles and energy usage, to the treatment group.

The control group customers also participated in IES; therefore, we assume that they are generally similar (in terms of housing stock, income eligibility, and consumption habits) and offer a reasonable counterfactual for participants in 2015 and 2016. We will include documentation in the final report comparing the pre-IES energy consumption and measure mix (i.e., the IES measures installed) of the treatment and control groups. It is also unlikely that many of these "future" IES participants made many of the energy efficiency improvements offered through the program prior to participating, which means the billing analysis results will be closer to gross than net savings (although the exact location on the gross-to-net savings continuum varies by measure, as described earlier in the plan).

Are billing analysis results gross or net?

The answer depends on the customers in the control group and the measure being analyzed. Since LEDs are readily available and relatively affordable, it's possible—even likely—that some customers in our control group of future IES participants installed some number of LEDs themselves prior to participating. As a result, the billing analysis results for LEDs is something between gross and net, albeit closer to gross (considering the substantial number of LEDs installed during most IES audits). Conversely, it's unlikely that many customers in our control group of future participants installed insulation outside IES. Therefore, that result can readily be interpreted as a gross savings value.

Our team will use the quasi-experimental matched control group (MCG) method to identify a specific "best match." The team's MCG approach will use a nearest-neighbor algorithm to match each treatment customer to a specific control group customer. In other words, the MCG approach results in a one-to-one match between a specific treatment and a specific control group customer based on both customers' energy consumption pattern over the 12 months prior to the treatment customer's participation in IES.

Our MCG approach does allow for one-to-many mapping, that is, a customer in the control group can potentially be the "best match" for more than one customer in the treatment group. As discussed during the kick-off meeting, our team will explore matching treatment group participants to more than one control customer and conduct a scenario analysis to determine whether model fit and/or estimated savings differ between the two matching scenarios.

Controlling for Non-IES Measures

At the kick-off meeting we also discussed another low-income-specific issue critical to accurate billing analysis results: accounting for the potential conflation of savings generated by IES measures and measures installed by participating Community Action Agencies (CAAs) using non-National Grid funding.

National Grid provided a file with detailed information about the actions taken at IES participating homes using non-National Grid funding. As anticipated, these actions include a mix of energy efficiency improvements (e.g., air sealing, heating system replacement, etc.), and health and safety-related improvements that do not impact a participant's energy consumption (e.g., ramps and dryer venting). In total, the provided file included information for 4,914 unique customers and 47,652 line items.

Our team mapped the customers in the non-National Grid funding file to the 2015 and 2016 IES participants. We found that 3,253 (33%) of the customers in our treatment group received at least one energy efficient measure using funding outside of IES. The team will include the dwelling-level savings in the billing analysis model to control for their presence and ensure they are not conflated with National Grid funded measures.

Model Specification

Our team will use a monthly Post Program Regression (PPR) model to estimate average measure-specific savings for the measure and fuels shown in Table 21. The general form of our PPR model follows[16]:

$$ADC_{ct} = b_1 Treatment_c + b_2 LagADC_{ct} + \sum_{month\ i} b_{3i} Month_{it} + \sum_{month\ i} b_{4i} Month_{it} * LagADC_{ci} + b_5 NonIES_c + \mathrm{e}_{ct}$$

Where

- ADC_{ct} = average, daily energy consumption for customer *c* at calendar month *t*
- $Treatment_c$ = 1 if customer *c* is in treatment group, 0 if customer *c* is in control group.
- $LagADC_{ct}$ = average daily consumption from customer *c* during calendar month t of the pre-program period
- $Month_{it}$ = 1 when index i = calendar month t, 0 otherwise. We include this series of 12 terms to capture month-specific effects in our analysis.
- $NonIES_c$ = 1 if customer c received a non-IES energy-efficiency or health and safety-related improvement.
- e_{ct} is the error term from the regression model.

In the model above, we derive annual, measure level savings from the coefficient b_1, which represents the average daily savings (kWh for electric, therms for natural gas) attributed due to the program. We may augment the general model shown above with terms that characterize the dwelling (i.e. attached/detached, size) and characterize other IES measures that impact same-fuel consumption to augment the general model described above if those terms sufficiently improve how the model fits.

[16] If we need to estimate savings for more than one weather-sensitive or base load measure, we will add the appropriate terms for each measure.

To normalize energy savings that are weather sensitive, we will use customers' zip codes to capture customer specific TMY3 weather data. We will get an annual average HDD by using customers in the analysis and use that to extrapolate average daily savings to an annual level.

Engineering Algorithms Details

Concurrent with the billing analysis, our team will estimate savings for a subset of measures using the engineering algorithms from the Rhode Island technical reference manual (TRM). Since National Grid will use the results of this study prospectively (to inform IES program planning in 2019 and beyond), our team utilized the most recent TRM (2018).[17]

To begin, our team identified each IES measure within the TRM.

Table 23. TRM Summary of IES Measures Included in Engineering Algorithm Analysis

		Annual Savings (TRM)**			
IES Measure Name	**TRM Name**	**Electric (kWh)**	**Natural Gas (therms)**	**Heating Oil (mmBTU)**	**Propane (mmBTU)**
AC Replacement (Window Unit)	Window AC Replacements	100	N/A	N/A	N/A
AC Timer#	N/A	0	N/A	N/A	N/A
Appliance Removal	Appliance Removal	1,180	N/A	N/A	N/A
CFL*	N/A	N/A	N/A	N/A	N/A
Clothes Washer and Dryer**	EnergyStar Dryer	160	N/A	N/A	N/A
Dehumidifier**	Dehumidifier	239	N/A	N/A	N/A
Domestic Hot Water (Aerators or Showerheads)	DHWater Measure	134	0.9	0.7	N/A
Education Materials (TLC kits)	Basic Educational Measures	138	N/A	N/A	N/A
Freezer Replacement	Replacement Freezer	484	N/A	N/A	N/A
Heat Pump Water Heaters	HPWH 50 gallon (electric)	1,775	N/A	N/A	N/A
LED Bulbs*	Varies	38.7	N/A	N/A	N/A
LED EISA EXEMPT*	LED Bulbs (EISA Exempt)	52.4	N/A	N/A	N/A
LED Reflectors*	LED Reflector	57.2	N/A	N/A	N/A
Programmable Thermostats	Programmable thermostat	214.60	31	3.1	N/A
Refrigerator Replacement*	Refrigerator rebate	384	N/A	N/A	N/A
Smart Strip*	Smart Strips	75.10	N/A	N/A	N/A
Waterbed	Waterbed mattress replacement	872	N/A	N/A	N/A

[17] http://www.ripuc.org/eventsactions/docket/4755-NGrid-2018-TRM-RI.pdf

* Also included in the billing analysis
**Some of the savings values in the table reflect the savings IES is claiming in 2018 and do not match the current TRM value
#AC timers are not included in the TRM and the measure data indicates no savings were claimed

Next, our team reviewed the engineering algorithm associated with each measure. For nearly every measure, the TRM includes the same basic gross savings algorithm:

$$Gross_{kWh} = Qty\ x\ deltakWh$$

For more detail regarding how to calculate *deltakWh*, the TRM typically references a previous evaluation. For example, the showerheads measure in the TRM points the reader to the Massachusetts Low-Income Multifamily Initiative Impact Evaluation completed in 2015 by The Cadmus Group, for more details. Our team searched out these evaluations and identified the relevant information within to bring more detail to the deltakWh term in Rhode Island's TRM. In the case of showerheads, the aforementioned evaluation used the following algorithm to estimate savings:

Shower water energy saved = shower water use reduction (Temperature of shower - Temperature of incoming cold water) * conversion to energy/water heater recovery efficiency*

*Shower water use (gallons/year) = household members * showers per capita per day * shower length * proportion of showering activity affected by replacement * as-used water flow rate*

In other instances, the referenced evaluation does not include an algorithm, but rather an energy savings estimate developed using an alternative evaluation method, such as billing analysis or building simulation. In these instances, our team will utilize well-established industry engineering algorithms to estimate savings. Whenever possible, we will rely on the current Massachusetts TRM[18] if the Rhode Island TRM is insufficient.

After identifying the relevant algorithm, our team will search out the associated algorithm inputs in the IES measure data provided by National Grid. For the case of showerheads, we found the inputs for "household members" and "number of showerheads installed" in the provided data, but not baseline flow rate or hot water setpoint temperature. (Other inputs, such as shower length, are available through well-established secondary sources.)

In general, the measure data provided by National Grid did not include very much information regarding baseline (pre-program) conditions or about the characteristics of the participant's home beyond their space and water heating fuel types. Consequently, our team submitted an additional data request to National Grid for the following types of information.

- Square footage (of SF detached home or unit)
- Number of stories
- Pre- and post-program attic insulation r-values, as well as associated square footage
- Pre- and post-program wall insulation r-values, as well as associated square footage
- Pre- and post-program basement ceiling insulation r-values, as well as associated square footage
- Pre- and post-program measured CFMs

[18] http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf

- Pre- and post-program measured duct leakage

National Grid is currently processing this request. If National Grid cannot provide the above information within the timeline of this study, our team will rely on secondary sources. As with the algorithms themselves, our team will look first to the most recent Low Income evaluation completed in Rhode Island[19], and then, if necessary, the most recent similar evaluation in Massachusetts.[20]

Building Simulation Details

The lack of specificity in the provided IES measure data and subsequent data request also has ramifications for the building simulation. As noted previously, our team will use building simulation on a small subset of IES measure that generate (or are subject to) interactive effects or that do not readily lend themselves to engineering algorithms or billing analysis

Ideally, we will populate our BEopt model (software created by the National Renewable Energy Laboratory that utilizes the Department of Energy's EnergyPlus as its simulation engine) with as much primary IES participant, household and measure data as possible. The extent to which our team can rely on IES-specific data, rather than secondary sources such as evaluation in Massachusetts, will depend largely on National Grid's ability to fulfil the request above.

Regardless, we expect to model at least two prototype buildings—single-family detached homes and multi-unit residences—to develop unique building simulation results for each specific fuel type. We will ensure accurate results and consistency with the billing analysis by calibrating each simulation model using participant energy consumption data, which National Grid has already provided. Specifically, we will calibrate the models based on the average total pre-program energy consumption and average heating-related energy consumption. These efforts will ensure that the building simulation is as consistent as possible with the billing analysis and engineering analysis.

Updated Deliverables and Schedule

[19] http://rieermc.ri.gov/wp-content/uploads/2018/03/national-grid-rhode-island-income-eligible-services-impact-evaluation-volume-ii.pdf

[20] http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Program-Impact-Evaluation_Part-of-the-Massachusetts-Residential-Retrofit-Low-Income-Program-Area-Evaluation.pdf

Table 18 lists these deliverables and the date our team will submit each to National Grid. Due to IES data arriving later than anticipated, the deliverable schedule has shifted slightly since the workplan.

Table 24. Updated Evaluation Deliverables and Schedule

Deliverable/Event	Date
Data Request (**Submitted**)	April 26th
Work Plan (**Submitted**)	May 1st
Kick-Off Meeting **(Held)**	May 14th
Data Request (**Fulfilled**)	June 15th
Work Plan (**Final**)	May 23rd
Data Review and Analysis Plan Memo (**Draft**)	July 3rd
Data Review and Analysis Plan Memo (**Final**)	July 20th
Preliminary Results Presentation	Week of July 30th
Evaluation Report, including engineering algorithm workbooks (**Draft**)	TBD
Evaluation Report, including updated engineering algorithm workbooks (**Revised**)	TBD
Evaluation Report, including engineering algorithm workbooks and copies of all building simulation files (**Final**)	August 24th