ENERGYWISE

Impact Evaluation of 2014 EnergyWise Single Family Program

National Grid Rhode Island

Date: 8/16/2016

Prepared by:

Thomas Ledyard
Jeremiah Robinson
Romilee Emerick
Divita Bhandari

DNV GL

Copyright © 2016, DNV GL (KEMA, Inc.)

This document, and the information contained herein, is the exclusive, confidential and proprietary property of DNV GL and is protected under the trade secret and copyright laws of the United States and other international laws, treaties and conventions. No part of this work may be disclosed to any third party or used, reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system, without first receiving the express written permission of DNV GL. Except as otherwise noted, all trademarks appearing herein are proprietary to DNV GL.

Table of contents

List of figures

List of tables

1 EXECUTIVE SUMMARY

This report presents the results of DNV GL's evaluation of National Grid Rhode Island's 2014 EnergyWise program. EnergyWise is designed to achieve energy savings in single family (1-4 unit) residential homes by directly installing efficient lightbulbs and water heating measures, providing devices for homeowner use, and offering building shell retrofit rebates. The core methodological evaluation approaches included a two-stage billing analysis and engineering verification/calculation work.

This evaluation fulfills the following evaluation objectives:

- Determine the average electric and gas savings by impact group.
- Provide estimates of light emitting diode (LED) lighting savings by number of bulbs.
- Calculate a realization rate for natural gas at the whole-house level, and for electric at the impact-group level.

During the course of the project several additional objectives were included, namely:

- Determine average electric and gas savings and realization rates by household for some measures and at the measure level for others.
- Review the natural gas weatherization tracking data and RISE[1] database for consistency and accuracy, and to try and determine the reasons that savings were overstated.
- Include 2015 participants who also participated in 2014 in the billing analysis in order to show the effects of multi-year participation.

1.1 Methodology

To develop savings estimates for the EnergyWise program DNV GL performed the major analysis tasks below.

- Created sample
- Created comparison group
- Two-stage billing analysis
- Engineering calculations
- Scaling savings estimates
- Expansion to population

Section 2 of this report provides a more detailed discussion of the methodology used for this analysis. The most notable feature is that savings for all the measures in the population add up to the savings predicted by the billing analysis for the program overall. This means the overall program savings estimates are accurate. The only significant remaining source of gross savings uncertainty is the portion of that overall savings which is allocated to each individual measure.

Table 1-1 shows the general approaches we took to estimate savings for each impact group. The "Basic Install Package" refers to the standard combination of measures installed in nearly every participant household, which are:

[1] RISE Engineering is the implementation contractor for the EnergyWise program.

- Compact fluorescent lightbulbs (CFL)
- Light emitting diodes (LED)
- Smart strips
- Refrigerator brushes

Table 1-1: Methodological Approach to Calculating Savings by Measure and Primary Fuel Type

Category	Measure	Natural Gas	Electric
Weatherization	*Weatherization Overall*	Billing Analysis	<u>Results by Heating Fuel:</u> Electric: Billing Analysis Oil: Engineering Verification Gas: Engineering Verification
	Insulation Overall	Engineering Verification	
	Attic Insulation	Billing Analysis	
	Sidewall Insulation	Billing Analysis	
	Basement/Floor Insulation	Engineering Verification	
	Other Insulation	Billing Analysis	
	Air Sealing	Engineering Verification	
Thermostats	Wi-Fi Thermostat	--	Engineering Verification
	Programmable Thermostat	Billing Analysis	Billing Analysis
Basic Install Package	CFLs	--	Billing Analysis
	LEDs	--	Billing Analysis
	Smart Strips	--	Engineering Verification
	Refrigerator Brushes	--	Engineering Verification
Domestic Hot Water	Showerhead	Engineering Verification	Engineering Verification
	Faucet Aerator	Engineering Verification	Engineering Verification
	Pipe Wrap	Engineering Verification	Engineering Verification
Other	Refrigerator Replacement	--	Billing Analysis
	Light Fixtures	--	Engineering Verification
	Outdoor Fixtures	--	Engineering Verification
	Torchieres	--	Engineering Verification

Oil weatherization savings (gallons of oil) were estimated using engineering verification.

1.2 Results

The following tables show savings for natural gas and electric. "BA" refers to billing analysis and "ENG" to engineering verification.

The results shown in Table 1-2 and Table 1-3 (including those labeled "BA") will not exactly match the results from the billing analysis shown in Section 2.2. The realization rate will match for the program overall, but individual measure realization rates and savings per household values will not. The reason for this is discussed in the Engineering Calculations, Section 2.3. In brief, the results for individual measures were adjusted to satisfy two conditions:

- All measures receive a reasonable amount of savings, including those without statistically significant billing analysis results.
- Savings for all measures in the population add up to the overall savings predicted by the realization rate developed by the program-wide billing analysis

This is the reason that many measures show the same realization rate (eg. 28.8% for electric and 33.1% for gas).

The ex post electric results shown in Table 1-2 reveal a significant drop in savings for most measures compared to the ex ante estimates. This is due in part to light bulbs being installed in much larger quantities in each household than they were last time the program was evaluated, which we believe is causing a reduction in average hours of operation per bulb. The strongest realization rates are for electric weatherization, programmable thermostats, LEDs, and refrigerator replacement, all of which came from the billing analysis.

Table 1-2: Annual Ex Post Gross Savings by Measure for Electric

Category	Measure	Partici-pants	Percent of Savings	Ex Ante Savings Per Unit (kWh/year)	Ex Post Savings Per Unit (kWh/year)	Billing Analysis Result (for sample)	Units	Realization Rate	Source
Weatherization	Electric Heat	124	1.5%	1,558.0	782.2	965.0	Household	50.2%	BA
	Oil Heat	685	1.8%	336.0	96.9	--	Household	28.8%	ENG
	Gas Heat	2,039	3.9%	251.0	72.4	--	Household	28.8%	ENG
Thermostats	WiFi Thermostat	208	0.2%	104.0	30.0	--	Measure	28.8%	ENG
	Programmable Thermostat	101	1.2%	330.0	214.6	257.3	Measure	65.0%	BA
Basic Install Package	CFLs	6,249	48.9%	47.0	8.1	10.3	Measure	17.3%	BA
	LEDs[2]	8,206	24.9%	48.0	23.6	30.3	Measure	49.1%	BA
	Smart Strips	7,890	9.5%	75.0	21.6	--	Measure	28.8%	ENG
	Refrigerator Brushes	7,999	2.3%	37.8	10.9	--	Measure	28.8%	ENG
Domestic Hot Water	Showerhead	33	0.0%	118.9	34.3	--	Measure	28.8%	ENG
	Faucet Aerator	11	0.0%	126.9	36.6	--	Measure	28.8%	ENG
	Pipe Wrap	58	0.3%	115.6	33.3	--	Measure	28.8%	ENG
Other	Refrigerator Replacement	98	0.6%	770.0	460.8	590.8	Measure	59.8%	BA
	Light Fixtures	286	0.5%	65.0	18.8	--	Measure	28.8%	ENG
	Outdoor Fixtures	377	4.3%	156.0	45.0	--	Measure	28.8%	ENG
	Torchieres	31	0.0%	139.0	40.1	--	Measure	28.8%	ENG
Total	**Overall**	**9,898**	**100%**	**1,317.1**	**383.9**	**434.0**	**Household**	**29.1%**	**BA**

2 See Section 3.3.1 for forward-looking results for LED bulbs, which accounts for post-2014 changes in program design.

The ex post natural gas results shown in Table 1-3 also reveal significant drop in savings for most measures compared to the ex ante estimates. This is largely due to an issue with weatherization tracking and calculation, as discussed in Section 3.2. The most interesting finding is the strong and significant realization rate for natural gas programmable thermostats.

Table 1-3: Annual Ex Post Gross Savings by Measure for Natural Gas

Category	Measure	Partici-pants	Percent of Savings	Ex Ante Savings Per Unit (Therms/yr)	Ex Post Savings Per Unit (Therms/yr)	Billing Analysis Result (for sample)[3]	Units	Realization Rate	Source
Weatherization	*Weatherization Overall*	2,188	94.8%	339.8	110.9	107.8	Household	32.6%	BA
	Insulation Overall	2,186	67.5%	232.8	75.0	--	Household	32.2%	ENG
	Attic Insulation	1,634	40.0%	184.7	50.1	72.2	Household	27.1%	BA
	Sidewall Insulation	707	17.1%	182.9	65.4	103.9	Household	35.8%	BA
	Basement/Floor Insulation	1,171	6.0%	38.5	12.7	--	Household	33.1%	ENG
	Other Insulation	1,501	4.3%	21.8	13.9	21.9	Household	63.6%	BA
	Air Sealing	1,888	27.3%	109.0	36.1	--	Household	33.1%	ENG
Thermostats	Programmable Thermostat	800	4.9%	24.6	10.1	16.5	Measure	41.0%	BA
Domestic Hot Water	Showerhead	38	0.0%	5.7	1.9	--	Measure	33.1%	ENG
	Faucet Aerator	6	0.0%	2.4	0.8	--	Measure	33.1%	ENG
	Pipe Wrap	230	0.3%	1.9	0.6	--	Measure	33.1%	ENG
Total	**Overall**	**2,734**	**100%**	**275.9**	**90.7**	**91.0**	**Household**	**32.9%**	**BA**

[3] The column "Billing Analysis Result (for sample)" refers to the savings for that measure found by the billing analysis for the subset of the population included in the billing analysis sample. It is only included for measures which had statistically significant results as shown in the "Source" column. The number shown varies somewhat from the ex-post savings for reasons described in section 2.3.

Table 1-4 shows savings for weatherization of homes with oil heat. The Ex Ante savings came from the BO Reports, which include 19,843 total gallons of oil saved for 838 homes, or 23.7 gallons per home.[4]

Table 1-4: Annual Ex Post Gross Savings by Measure for Oil

Measure	Participants	Ex Ante Savings (MMBtu/Year)	Ex Post Savings (MMBtu/Year)	Units	Realization Rate	Source
Weatherization Overall	685	23.7	14.0	Household	59%	ENG

[4] This assumes that oil savings was calculated as a deemed value which could be obtained by dividing the number of homes into the total savings. The electric tracking data for oil weatherization participants had a number of duplicate deemed savings lines, an issue which was corrected in 2015. The stated 838 homes were reduced to 685 in the table for this reason.

1.3 Conclusions and Recommendations

This evaluation shows that the program is producing substantial electric and gas energy savings.

As mentioned earlier, the savings estimates produced by the billing analysis are significantly lower than that predicted by the tracking savings. The known reasons for this are as follows:

- **CFLs and LEDs**: Tracking savings for CFLs and LEDs were based on data extrapolated from the 2012 evaluation per-bulb analysis. These results appear not to be applicable going forwards, as discussed in section 3.3. Part of the reason may be that the average number of bulbs in 2012 was 9, while the average number in 2014 was 23, so the extrapolation may have been of limited applicability to the new program design. In 2015, the Energy Efficiency Resources Management Council consultants asked National Grid to switch the CFL and LED lighting assumptions to the Massachusetts (MA) Market Adoption Model which are based on MA programs and assumptions instead of Rhode Island. This resulted in a value which this billing analysis found to not be very applicable to Rhode Island. We suggest that the results of this evaluation are more applicable, and should be used going forwards, at least in 2017. It would also be possible to calibrate the Market Adoption model based on the results of this evaluation, as discussed in section 3.3.
- **Gas Weatherization**: Weatherization savings for natural gas heated households were not well reflected by the calculations used to produce the tracking data. This is the primary driver of the realization rate for the gas program. We explored the reasons for this in the tracking data as well as the RISE tracking database, and were not able to find a definitive answer. The potential unexplored reasons for this issue are as follows:
    - The baseline level of insulation in homes is not accurately recorded in the tracking data. For most measures, the baseline level is reported as zero, which is probably unrealistic.
    - We did not explore whether the savings estimates produced through the 2012 analysis were translated into calculations in such a way as to accurately reflect savings from program activities since 2012. If they were not, this could explain the low realization rates.
- **Refrigerators**: It is well known throughout the energy efficiency industry that refrigerator replacement savings are decreasing every year as older refrigerators built prior to manufacturing standards become increasingly rare. The realization rate for refrigerators reflects this.

Realization rates also have implications for cost-effectiveness. While they do not correspond directly, lower realization rates can have a downward effect on cost-effectiveness. This effect is currently being experienced at residential retrofit programs around the country , and program managers are wrestling with how to continue to run residential retrofit programs that are borderline cost-effective.

There are a number of reasons one might want to continue with a program like EnergyWise even if it were not cost-effective using the standard Total Resource Cost (TRC) test, including the following:

- Residential retrofit programs provide durable benefits to participants and to society in addition to energy savings, which are not reflected in the TRC. These include providing economic growth for Rhode Island by primarily hiring contractors based in the state,[5] as well as carbon reductions.
- Home weatherization programs reach customers at important milestones in their lives such as when they move or begin major home renovations. Because of this, they serve as an entry point for new participants into the program, which increases the odds that they will participate in other programs in the future.
- Programs like EnergyWise take a long time to ramp up and down, and the decision to stop running such a program is not one that can be reversed quickly. Many trade allies depend on EnergyWise for their business, and if they left this sector many of the most qualified could not or would not re-enter if the program were to restart.[6]

We recommend that the program administrator consider the following in the coming years of program implementation:

- Adopt the deemed savings estimates produced by this evaluation for use going forwards.
- Update the approach used to estimate energy savings for natural gas weatherization in the tracking system. This can include updating the prescriptive savings formulas used to match results from this evaluation, or a change to a deemed savings estimate.
- Consider using the results from this effort as a starting point for developing savings for LED bulbs in 2017. The numbers reported here are representative of savings from the portion of the 2014 program year that is likely to be most similar to 2017. However, if the program design—especially with regard to the numbers of LED bulbs installed per home—varies significantly from the design used in late 2014, another number such as the Massachusetts Market Adoption Model may be appropriate to substitute. We also recommend that National Grid consider in 2017 whether and how to update the savings estimates for LEDs going forwards. This study did not look into the issue of how well the late-2014 results represent program activity in 2015 and 2016. The fact that most households even in late 2014 installed both LEDs and CFLs suggests that they are not a perfect representation of a future in which only LEDs are installed. Options for updating savings estimates could include a review of tracking data from 2015-16, a literature review of results from other states, or an update to the billing analysis using 2015 data.
- In the future, we recommend that billing analyses include all measures installed by participants who began their participation in the analysis year, including those whose participation spanned multiple years, to the extent possible. At least for natural gas, we found that multi-year participants install more measures overall than single-year participants.

[5] Analysis of Job Creation from 2015 Expenditures for Energy Efficiency in Rhode Island by National Grid, Pergrine Energy Group (2015): http://www.ripuc.org/eventsactions/docket/4527-NGrid-YrEndRept(5-2-16).pdf

[6] http://blogs.dnvgl.com/energy/realizing-the-promise-of-wh-retrofits

2 METHODOLOGY

To develop savings estimates for the EnergyWise program DNV GL performed the following major analysis tasks:

1. **Created Participant Sample.** We compiled a sample of 2014 program participants which met the following criteria:

    - Participated in the EnergyWise program but not the High Efficiency Heating Equipment (HEHE) or HVAC programs[7]
    - Had sufficient billing data from both 2013 and 2015
    - Billing data showed a reasonable usage pattern suggestive of a single-family home.
    - Participation began in 2014. In other words, there was no pre-2014 participation. We did include natural gas participants who participated in both 2014 and 2015.
    - Table 2-1 shows the savings and population associated with each measure.

Table 2-1: Summary of Tracking Data

Measure Category	Savings		Participants	
	Value (kWh or Therms)	Percent of Total	Count	Percent of Total
Electric				
CFLs	6,380,203	49%	6,249	63.13%
LED Bulbs	3,240,720	25%	8,206	82.91%
Other Lighting	634,560	5%	497	5.02%
Refrigerator Brush	303,356	2%	7,999	80.81%
Smart Strip	1,237,125	9%	7,890	79.71%
DHW	42,063	0%	102	1.03%
Thermostats	156,750	1%	101	1.02%
WiFi Thermostat	29,744	0%	208	2.10%
Refrigerator Rebate	77,000	1%	98	0.99%
Weatherization - Electric Heat	230,160	2%	124	1.25%
Weatherization - Oil Heat	193,192	1%	685	6.92%
Weatherization - Gas Heat	511,789	4%	2,039	20.60%
Total	**13,036,662**	**100%**	**9,898**	**100%**
Natural Gas				
Air Sealing	205,739	27%	1,888	69%
Attic Insulation	301,797	40%	1,634	60%
Sidewall Insulation	129,278	17%	707	26%
Basement Insulation	45,108	6%	1171	43%
Insulation Other	32,773	4%	1,501	55%
DHW	2,628	0%	252	9%
Thermostats	36,872	5%	800	29%
Total	**754,195**	**100%**	**2,734**	**100%**

[7] After comparing the results with HEHE/HVAC participants included or excluded, the billing analysis results were statistically the same. For this reason and because doing so simplifies the analysis, we excluded HEHE/HVAC participants

2. **Created Comparison Group**. We created a comparison group using the 2015 tracking database with the characteristics below. We used 2015 participants rather than another nonparticipant group based upon the assumption that 2015 participants and 2014 participants are similar in many ways with regard to how they use energy. The following criteria were applied:
    - Participants had not participated in any programs during the 2013-14 program years
    - Participants had sufficient billing data from both 2013 and 2015
    - Billing data showed a reasonable usage pattern suggestive of a single-family home
3. **Billing Analysis**. We performed a pre-post billing analysis using the two-stage PRISM modeling approach. This analysis compared our 2014 participant sample with the comparison group. This analysis was intended to develop savings estimates both for the program overall and for the impact group level. In some cases we were able to do so. For other cases, the lack of variation in which measures were installed in different households prevented an impact group level analysis.
4. **Engineering Calculations**. For impact groups where the billing analysis did not show statistically significant results, or where the results were desired at the measure level, our engineering team performed a literature review to allocate the overall billing analysis result to these impact groups or measures.
5. **Scaling Savings Estimates**. In order to make the savings estimates developed by the billing analysis and engineering calculations—created by the impact group—add up to the billing analysis results for the program overall, impact-level results had to be scaled. This task was performed by our engineers based upon the relative uncertainty of estimates for each measure. The outcome of this task is energy savings estimates for each EnergyWise impact group or measure, depending on program needs.
6. **Expansion to Population**. In this task, results from the previous tasks are applied to the program population at the impact group level or the measure level, depending on program needs. This will result in an estimate of savings for the 2014 EnergyWise program which is usable for program planning going forwards.

2.1 Comparison of Methods to Previous Evaluation

Table 2-2 and Table 2-3 show the evaluation approach taken in evaluating gas and electric measures in this study, respectively. They each also show the approach that was taken in the previous study (2012). The percentage of savings represented by these measures is shown. The final rows of each table show the percent of program savings that will be addressed by each study method. Note that measures which received "Engineering Verification" were scaled based upon the result of the overall program billing analysis to ensure the aggregate savings from the engineering work was the same as the billing analysis result.

For the 2014 evaluation, DNV GL used a two stage billing analysis approach as opposed to the pooled fixed effects model applied in the 2012 study. The two-stage approach allowed for estimating normalized annual consumption based on participants' optimal heating and cooling degree day bases. Each participant home has a unique degree day base due to its level of envelope insulation, infiltration, internal/solar gains, and thermostat set point schedule. This approach considers each premise's unique attributes and fully leverages the available information in the weather data rather than the pooled approach that imposes fixed degree-day bases on all sites.

The 2012 evaluation used Engineering Algorithms for a number of measures, and Simulation Modeling for others. Engineering Algorithms were developed based on a literature review of studies from other states, along with a series of assumptions made by engineers. Simulation modeling was done using a calibrated proprietary DOE-2 model, in which end uses were disaggregated primarily based on U.S. DOE's Building America Research Benchmark (BARB)[8] framework.

At a practical level, this round of evaluation provided a more advanced billing analysis than 2012. This billing analysis provided savings for all measures which made a significant (>10%) contribution to program savings. The remaining measures were allocated savings based on the portion of tracking data they represented (which was based on the results of the 2012 study in most cases), scaled so that all measures together match the overall program billing analysis result.

Table 2-2: Gas Measure Evaluation Approaches

Measure Type	Impact Category	% of 2014 Gas Savings	DNV GL Approach	2012 Approach
Weatherization	Attic Insulation	39.5%	Billing Analysis	Billing Analysis
	Sidewall Insulation	16.6%		
	Basement/Floor Insulation	6.1%	Engineering Verification	Simulation Modeling
	Insulation Other	3.9%	Billing Analysis	
	Air Sealing	28.2%	Engineering Verification	Billing Analysis
Other	Programmable Thermostats	5.2%	Billing Analysis	Engineering Algorithm
	Domestic Hot Water	0.4%	Engineering Verification	
Billing Analysis		62.5%		
Engineering Verification		34.7%		

8 U.S. Department of Energy. *Building America Benchmark Program Database.* 2010.

Table 2-3: Electric Measure Evaluation Approaches

Measure Type	Impact Group	% of 2014-15 Electric Savings	DNV GL Approach	2012 Approach
Weatherization	Oil Heat	1.5%	Engineering Verification	Simulation Modeling
	Gas Heat	3.9%	Billing Analysis	Simulation Modeling
	Elec. Heat	1.1%	Billing Analysis	Simulation Modeling
Thermostats	WiFi Thermostats	0.2%	Engineering Verification	Engineering Algorithm
	Setback Thermostats	1.2%	Billing Analysis	Engineering Algorithm
Basic Install Package	LED Bulbs	24.9%	Billing Analysis	N/A
	CFLs	49.0%	Billing Analysis	Billing Analysis
	Smart Strips	9.5%	Engineering Verification	N/A
	Refrigerator Brushes	2.3%	Engineering Verification	Engineering Algorithm
Domestic Hot Water	DHW	0.3%	Engineering Verification	Engineering Algorithm
Other Measures	Light Fixtures	4.9%	Engineering Verification	Billing Analysis
	Refrigerator Rebate	1.2%	Billing Analysis	Billing Analysis
Billing Analysis		81.3%		
Engineering Verification		18.7%		

2.2 Billing Analysis

The billing analysis conducted in this study was comprised of a two-stage approach where the first stage involved site-level modelling and the second stage applied a difference-in-differences method to measure program savings overall and by impact group. This approach estimates gross energy savings and relies on a comparison group consisting of subsequent participants to control for non-program related change. The method used in this evaluation is compliant with the International Performance Measurement and Verification Protocol (IPMVP) option Method C, Whole Facility, and was recently published in the Department of Energy's Uniform Methods Project (UMP) Whole-Building Retrofit Evaluation Protocol.[9]

We also produced a Statistically Adjusted Engineering (SAE) regression with dummy variables for each impact group and the corresponding expected savings. The inclusion of both impact group savings and dummy variables minimizes understated estimates of savings due to errors from omitted variable bias and allows us to estimate savings from the different impact groups. For this analysis, however, the SAE results were not significantly different from the standard model either in savings or precision, and so were not included in results.

Table 2-4 describes the tracking, billing, customer, and weather datasets used in this evaluation.

[9] The Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol. Chapter 8 of The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. NREL April, 2013. http://energy.gov/sites/prod/files/2013/11/f5/53827-8.pdf

Table 2-4: Datasets Used in Analysis

Data	Fuel	Source/File Name	Available
Tracking Data	Electric	SF_14_15_electric_oil.csv Copy of 2014_RI_EW_SF revised.xls	9,898 participants in 2014 2,734 participants in 2014
	Natural Gas		
Billing Data	Electric	WRS21953_BILLS.MDB	Jan 2011 to Dec 2015
	Natural Gas	WRS21953_BILLS.MDB WRS23968_BILLS_2016.MDB	Jan 2011 to Dec 2015 Jan 2016 to May 2016
Weather Data	N/A	Source: NOAA, NREL Actual weather data and TMY3[10]	Jan 2012 to May 2016

Table 2-5 summarizes the program population for participant and comparison groups and the final sample used in the billing analysis for both electric and gas. We limited our sample to ensure the quality of billing data used. The sample utilized in the final billing analysis included accounts that had the following:

- At least 10 billing months in the pre- and post-periods
- Did not participate in HVAC and/or HEHE program during the analysis period
- Passed all Quality checks including
  - Having no more than two estimated reads
  - No zero reads in the electric billing data and no more than 3 zero reads in the gas billing data.
  - Accounts that had outliers based on the site level modeling
  - Customers with poor fits for normalized annual consumption

[10] NOAA: National Oceanic and Aviation Administration, NREL: National Renewable Energy Laboratories, TMY: Typical Meteorological Year

Table 2-5: Customers Used in Billing Analysis

Data Disposition	Count	
	Electric (kWh)	Gas (therm)
Initial no. of accounts		
Participant Group	9,898	2,734
Comparison Group	11,626	2,746
Removed insufficient data and participants that started installations before 2014		
Participants	4,721	1,021
Comparison Group	5,325	1,242
Removed other data issues		
Participants	212	120
Comparison Group	356	121
Final analysis data[11]		
Participants	4,965	1,593
Comparison Group	5,945	1,395

This analysis focused on program year 2014 and removed participants that started participating prior to 2014. This is a standard practice in billing analyses, as it avoids confounding effects and reduces the amount of data cleaning dramatically. In most cases, this single year analysis is sufficiently representative of the population. However, based on a suggestion from the program administrator that multi-year EnergyWise natural gas participants may be performing more total measures than single-year participants, we included natural gas participants who completed measure installations in both 2014 and 2015, to the extent that sufficient billing data was available. This effort found that multi-year participants install more natural gas measures. Including these participants in the final analysis provides a better representation of the mix of program participants being evaluated. In the future, we recommend that billing analyses include all measures installed by participants who began their participation in the analysis year, to the extent possible.

Table 2-6 shows a comparison of measures installed by the population and analysis sample for both the comparison and participant groups. This table illustrates that the distribution of savings across the different impact groups in the population and final analysis sample are very similar, even after removing accounts due to the reasons provided above. This suggests that the comparison group is a good match. One apparent exception is LEDs and CFLs, in that the comparison group installed primarily LEDs rather than CFLs. However, this is unlikely to confound the results because both groups installed similar numbers of lightbulbs overall, which suggests that their participation behaviors are similar.

[11] The analysis for gas included 2014 participants that also installed measures in 2015

Table 2-6: Comparison of Measures Installed in Comparison and Treatment Groups

Measure Category	Population				Sample			
	Savings		Percent savings		Savings		Percent savings	
	Treatment	Comparison	Treatment	Comparison	Treatment	Comparison	Treatment	Comparison
Electric								
CFLs	6,380,203	1,187,021	49%	6%	3,771,421	567,347	51%	5%
LED Bulbs	3,240,720	14,514,339	25%	75%	1,903,008	8,883,984	26%	79%
Other Lighting	634,560	777,612	5%	4%	248,857	321,568	3%	3%
Refrigerator Brush	303,356	350,686	2%	2%	170,973	209,309	2%	2%
Smart Strip	1,237,125	1,488,225	9%	8%	718,200	875,700	10%	8%
DHW	42,063	3,528	0%	0%	19,605	1,568	0%	0%
Thermostats	156,750	256,054	1%	1%	71,610	129,704	1%	1%
WiFi Thermostat	29,744	13,624	0%	0%	13,416	4,472	0%	0%
Refrigerator Rebate	77,000	50,820	1%	0%	42,350	26,950	1%	0%
Weatherization - Electric Heat	230,160	330,960	2%	2%	94,080	147,504	1%	1%
Weatherization - Oil Heat	193,192	274,208	1%	1%	59,204	101,270	1%	1%
Weatherization - Gas Heat	511,789	NA	4%	NA	283,630	NA	4%	NA
Total	**13,036,662**	**19,247,076**	**100%**	**100%**	**7,396,354**	**11,269,376**	**100%**	**100%**
Natural Gas								
Air Sealing	205,739	137,674	27%	18%	127,189	67,445	29%	18%
Attic Insulation	301,797	425,909	40%	56%	168,616	218,507	39%	58%
Basement Insulation	129,278	21,148	17%	3%	72,656	9,429	17%	3%
Insulation Other	45,108	19,138	6%	3%	18,197	10,012	4%	3%
Sidewall Insulation	32,773	92,651	4%	12%	23,364	35,536	5%	10%
DHW	2,628	5,711	0%	1%	24,715	29,645	0%	8%
Thermostats	36,872	54,947	5%	7%	1,636	3,166	6%	1%
Total	**754,195**	**757,178**	**100%**	**100%**	**436,373**	**373,740**	**100%**	**100%**

2.2.1 Site-Level Model Results

Normalized Annual Consumption (NAC) was estimated for the pre- and post-installation periods using the optimal degree-day base for each participant site. Table 2-7 compares the average actual and normalized consumption level between the pre- and post-periods for participating electric and gas accounts in the analysis. Results show that, on average, participating electric households reduced their normalized annual consumption 5% while participating gas households reduced their normalized energy consumption by 10%. During this same period, our electric comparison group experienced a decrease in normalized consumption of less than 1% while the gas comparison group reduced consumption 2%. These changes in consumption among the comparison group represent the change in consumption from pre-to post-periods that are not program related and are used to adjust the change in consumption observed for the participant group to isolate program effects.

Table 2-7: Average Actual and Normalized Pre/Post Electric and Gas Consumption

Consumption	Electric (kWh)			Gas (Therms)		
	Pre	Post	% Change	Pre	Post	% Change
Actual Consumption						
2014 Participants	9,301	8,752	-5.91%	1,112	1,031	-7.31%
Comparison	9,678	9,627	-0.53%	1,123	1,144	1.91%
Normalized Consumption						
2014 Participants	9,274	8,807	-5.03%	1,100	985	-10.44%
Comparison	9,661	9,628	-0.33%	1,115	1,091	-2.17%

Figure 2-1 and Figure 2-2 provides a graphical illustration of the information provided in Table 2-7.

Figure 2-1: Comparison of Average Actual and Normalized Electric Consumption

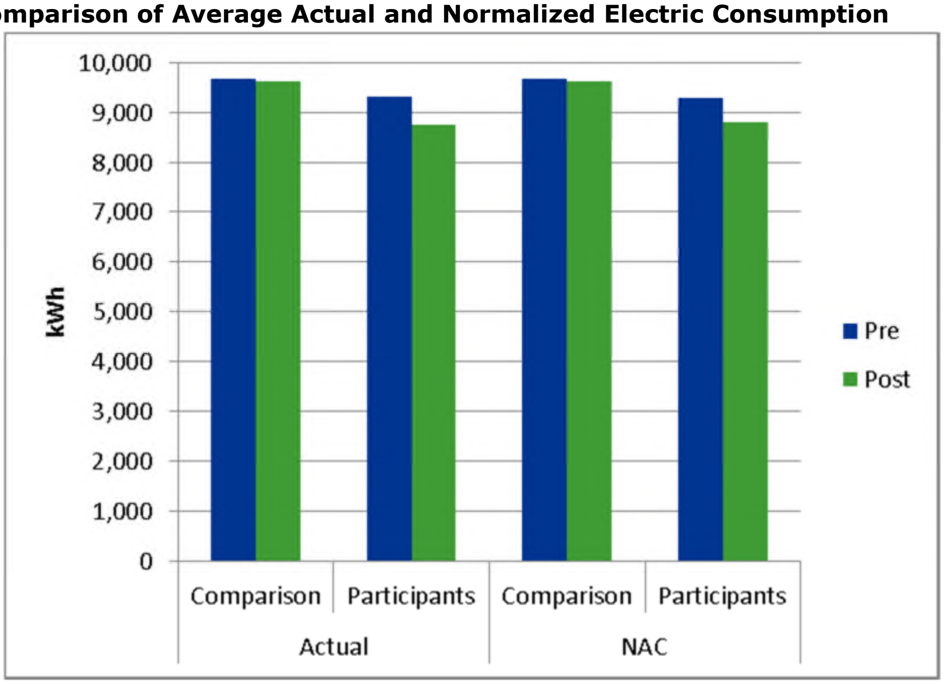


Figure 2-2: Comparison of Average Actual and Normalized Gas Consumption

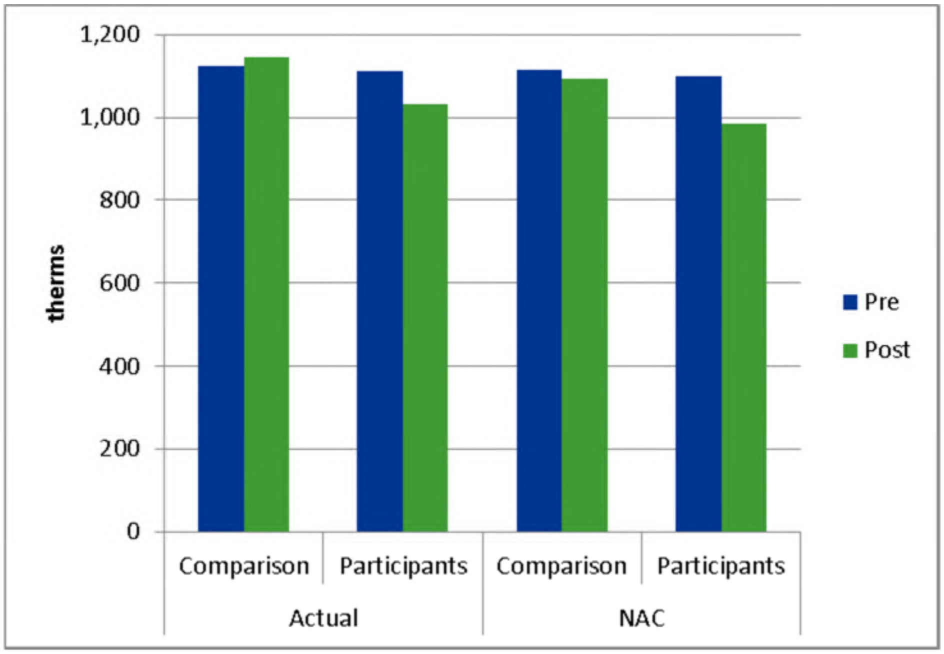


Table 2-8 summarizes the average normalized annual cooling-degree days (CDD) and heating-degree days (HDD) based on the optimal base temperatures of the participants and comparison groups used in the analysis. CDD decreased between pre and post while HDD increased from pre to post periods for both participant and comparison group. These changes in CDD and HDD between pre- to post periods is consistent with the change observed in the average actual electric and gas consumption of the participant and comparison group.

Table 2-8: Summary of CDD and HDD

Average Annual Degree Days	Participants		Comparison	
	Pre	Post	Pre	Post
Electric				
CDD	285	256	288	262
HDD	4,362	4,454	4,333	4,471
Gas				
HDD	4,163	4,348	4,164	4,421

2.3 Engineering Calculations

This portion of the evaluation was originally designed to be parallel and at least partially independent of the billing analysis. However, as the evaluation moved forward it became increasingly apparent that the primary value offered by this evaluation overall was to provide an accurate estimate of program-wide savings and of the measures which offered the largest savings.

This approach relegated the engineering work to the supporting role of assessing the impacts of measures unable to be quantified in the billing analysis. A key part of this was to have the final estimate of all measure level savings fit under the estimates for the program overall as determined in the billing analysis. This was done in two stages, described here:

1. Scale the savings estimates of all billing analysis measure categories to match the overall program savings billing analysis results. This involves two parallel steps, shown below. For more on this first stage, see Section 2.3.2.
    - Assign savings to measures in the sample which did not receive statistically significant billing analysis savings estimates based on the proportion of tracking savings associated with that measure category in the sample.
    - Adjust savings for both statistically significant and non-statistically significant measure categories proportionally so that the total savings matches the program-wide billing analysis result at the population level.
2. Apply the savings estimates created under Stage 1 for billing analysis measure categories to specific measures where requested.

In brief, the billing analysis produced savings results for the program overall, and statistically significant savings for certain individual measures and groups of measures. The engineering calculations then made sure that all measures were allocated an appropriate amount of savings, and that all the estimates together added up to the total.

2.3.1 Adjustments to Specific Measures

Once all measure savings were estimated based on the billing analysis, we sought to adjust the proportions of overall savings allocated to impact groups and measures based on engineering judgment and literature review. This affects measures without statistically significant billing analysis results.

The core approach to making specific adjustments to this was to look at secondary sources (TRMs, impact studies, etc.) to see if the measures scaled down from the billing analysis required modification. After reviewing the primary non-statistically significant measure savings, the engineer performing the review chose not to make any specific savings reallocations for engineering reasons. For the primary measures examined (those representing greater than 2% of program savings), we found that the scaled down measure savings estimate either remained within the range of possible savings based on the literature review or lacked a definitive way to perform an adjustment that we believed appropriate. Table 2-9 and Table 2-10 includes a discussion of the engineering review of gas savings. Because the air sealing measure is the only statistically significant measure which represents a significant portion of program savings, we limited our review to this measure.

Table 2-10 include comments on measures that we considered making adjustments to, and the reasons why we chose to leave them unchanged.

Table 2-9: Engineering Review of Electric Savings

Oil & Gas Weatherization (electric savings)
• In our analysis, weatherization in oil-heated homes shows higher electric savings than natural gas-heated homes. This seems counterintuitive, since natural gas is more commonly seen with furnaces which include fan energy use. However, the previous evaluation found oil weatherization to produce higher electric savings and our current study did not have statistically significant results that disagreed. • One reason that oil-heated homes could save more electricity include that they may be larger or older-vintage homes, on average, which would cause them to save electricity from weatherization on the cooling side. • We were not able to compare measures directly, since information supporting estimates such as the square footage of the building or pre-post R Values were not available for electric savings. However, Table 3-9 shows some indication that oil heated homes may have received more insulation on average, depending on the meaning of the field "Quantity." • We chose not to adjust savings further, beyond the adjustments already made, because we did not have justification for doing so based on the information available to us.

Smart Strips
• Our current estimate of 21.6 kWh/unit is in line with what research suggests, even if lower than tracking 75kWh. According to a white paper,[12] looking at 12 TRMs across the country, savings range from 10kWh to 103 kWh. • The 75 kWh savings in the tracking system comes from a frequently cited NYSERDA study[13] that says that smart strips are estimated to save 75.1 kWh on entertainment systems and 30.1 kWh on IT systems. The report concluded that the configuration (type of equipment) plugged into the smart strip can significantly impact savings. This paper also states that there is little research for this measure since it usually is small percentage of portfolio. • The Rhode Island Multifamily Impact Evaluation[14] passed through the tracking estimate of 78.3 kWh under the household that while this estimate may be high, it can still be considered reasonable. Several studies were reviewed as part of that evaluation. A study by e-source[15] shows savings in RI ranged 23 kWh to 184 kWh with 80 kWh average savings. An OPA impact evaluation[16] showed a savings or 16.9 kWh. Again, these studies show the wide variation in savings for this measure. • Another factor suggesting a lower savings value than 75 kWh is that the program provided 2.1 smart strips on average, suggesting that many households would not use all of them on the most energy-saving applications. • Overall, we believe that the estimate of 21.6 kWh is appropriate to use considering the overall program realization rate and the magnitude of savings for other measures relative to their expected ranges.

[12] *Overview of the Tier 1 Advanced Power Strip: Potential Savings and Programmatic Uses.*
[13] NYSERDA, *Advanced Power Strip Research Report*. Albany, NY: August 2011.
[14] DNV GL, *Multifamily Impact Evaluation National Grid Rhode Island*. January 2016.
[15] ILLUME Advising, LLC, *Overview of the Tier 1 Advanced PowerStrip: Potential Savings and Programmatic Uses.* September 2014. http://www.efi.org/docs/studies/esource_aps.pdf
[16] We note that this study also cited an evaluation of smart strips in New Hampshire; however, that source appeared to also contain planning savings estimates and not formally evaluated estimates.

Refrigerator Brushes
• Our current estimate of 10.9 kWh is in line with what research suggests. However, there is little research about this measure. • The tracking savings, 37.8 kWh, is from the 2012 single family evaluation.[17] This is based on a 1993 study[18] claiming 3% energy savings for cleaning once per year and an assumed baseline typical Energy Star refrigerator consumption of 1,225 kWh. • If 3% is reasonable, average new refrigerators might be much lower, Efficiency Vermont[19] shows 2001-08 vintage 19-21 ft3 side-by-side refrigerators at 686 kWh and new units at 381 kWh, which would put savings at 20.6 kWh and 11.43 kWh, respectively. • Overall, we believe that the estimate of 10.9 kWh is appropriate to use considering the overall program realization rate and the magnitude of savings for other measures relative to their expected ranges.

Table 2-10 includes a discussion of the engineering review of gas savings. Because the air sealing measure is the only statistically significant measure which represents a significant portion of program savings, we limited our review to this measure.

[17] The Cadmus Group Inc., *Rhode Island EnergyWise Single Family Impact Evaluation*. Portland OR: October 2012.

[18] *SMUD's Refrigerator Graveyard: Conditions of the Deceased*, Home Energy Magazine Online, January/February 1993. Accessed online 20 September 2012. http://www.homeenergy.org/show/article/nav/refrigerators/page/4/id/915

[19] Efficiency Vermont, *Electric Usage Chart Tool*, Online Accessed online 14 July 2016. https://www.efficiencyvermont.com/tips-tools/tools/electric-usage-chart-tool

Table 2-10: Engineering Review of Gas Savings

Air Sealing
• Air sealing is the largest measure in the program for which the billing analysis did not find statistically significant energy savings. This is in part due to the fact that nearly every home which received weatherization also had a blower door test and claimed air sealing savings. This makes it difficult for a billing analysis to find distinguishable savings. • However, the fact that nearly every natural gas weatherization participant does air sealing also makes it less important to distinguish savings for specific measures, assuming that the program continues to offer this measure into the future. Whether savings are allocated to air sealing or attic insulation becomes less important when nearly everyone does both. • A literature review of air sealing measures found that most programs nationwide use the same TRM algorithm as Rhode Island, with largely the same assumptions. • One assumption that may be incorrect is that the existing furnace AFUE is 76%. Our experience suggests that actual installed furnace efficiency in the Northeast is more like 85-90%, which is also suggested by other literature.[20] • The reduction in air leakage for air sealing measures is indicated in tracking data as the CFM50_PRE and CFM_Post fields, based on pre-post blower door tests of each participant home. The average reduction in airflow for gas air sealing entries in the tracking data is 32%. A fifth of the entries have a 50% reduction or higher in airflow. This is somewhat higher than might be expected for this measure. The EPA, using some building stock assumptions, makes a savings estimate for air sealing on a typical home of 12% annual energy usage. It is possible that there are some measurement accuracy issues with regards to the air leakage in the tracking data.[21] Comparing 12% by 32% brings us very close to the realization applied in this evaluation. • Overall, we believe that applying the overall realization rate to air sealing provides an estimate in the expected range, representing likely magnitude of savings.

2.3.2 Modifications to Billing Analysis Results

The nature of billing analysis is that the model for each home allocates savings to the various measures known to have been installed in that home. When many homes had the same mix of measures installed, billing analysis models have trouble allocating those savings accurately. In the case of this analysis, savings were allocated to the largest measures in such a way that the savings of those measures added up to the total savings for the program overall. This left very little remaining savings to allocate to other measures which did not receive statistically significant billing analysis results.

In order to appropriately account for these other measures, savings for statistically significant measures had to be reduced. We chose to approach this issue by initially providing all non-statistically significant measures with a single realization rate. We applied the billing analysis realization rate found for the sample (29.1% for

[20] http://energy.gov/energysaver/furnaces-and-boilers shows mid to high efficiency units with AFUE of 80-98.5%

[21] https://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_methodology

electric and 32.9% for gas), adjusted so that when expanded from the sample to the whole population the overall realization rate matched the sample realization rate. The values that provided this result were 28.8% for electric and 33.1% for gas.

3 RESULTS

This section includes detailed results of the tracking billing analysis, data review, and engineering evaluation.

3.1 Energy Savings Results

This section presents summaries of key parameters, as well as results of the billing analysis and savings estimates, by fuel, measure, and for the program overall. Throughout this section, rows labeled "Overall" refer to averages across any household that installed at least one measure in that category.

Table 3-1 shows the estimated savings per household for electric/gas participants for the respective fuels. Electric savings are reported in kWh and gas savings are reported in therms. Additionally, the number of sample participants in the final analysis that adopted electric / gas measures have been provided. The resulting savings for each fuel are statistically significant. Gas has a higher realization rate and a higher percentage of savings as a percentage of the normalized consumption.

Table 3-1: Overall Results by Fuel Type from Difference of Differences Model with Comparison Group

Fuel	N	Estimated Savings per Household	Standard Error	Precision @ 90% Confidence	Pre-NAC per Household	Savings as Percent of Pre-NAC	Tracking Savings	Realization Rate
Electric (kWh)	4,965	434	42.40	±16%	9,274	4.7%	1,490	29%
Gas (therms)	1,593	91	6.69	±12%	1,100	8.2%	274	33%

3.1.1 Natural Gas

This section includes results broken out by weatherization and domestic hot water measures, as well as overall results for program participants with natural gas space and/or water heat.

3.1.1.1 Weatherization

Key parameters from the tracking data for the natural gas weatherization measures are shown in Table 3-2. For a comparison to the previous round of evaluation for these values and a discussion of the reasonableness of the savings inputs, see Table 3-15. One concern is that most measures show an R-Value of zero in the pre-installation case.

Table 3-2: Weatherization Tracking System Values and Savings per Home

Category	2014 Tracking Data				
	Homes	Ft2/ Home	Pre-R-Value	Post-R Value	Savings/Home
Attic Insulation	1,888	1,739	6.7	29.2	184
Sidewall Insulation	1,634	1,508	0.0	13.0	182
Basement Insulation	707	1,686	0.0	20.3	38
Other Insulation	1,171	1,725	0.0	0.0	14
Air Sealing	1,501	1,729	--	--	107
Weatherization Overall	**2,103**	**--**	**--**	**--**	**339.8**

Table 3-3 shows the billing analysis results for natural gas weatherization savings. Measures with statistically significant savings include attic insulation, sidewall insulation and other insulation. Individually, these measures represent between two and ten percent of preprogram gas consumption.

Table 3-3: Billing Analysis Energy Savings Results for Weatherization Measures

Measure	N	Avg. Household Energy Savings (therms/year)	Relative Precision at 90% Confidence Level	Average Household Pre-NAC	Average Household % Savings
Attic Insulation*	998	72.23	±30%	1,097	6.58%
Sidewall Insulation*	394	103.93	±17%	1,041	9.98%
Basement/Floor Insulation	694	3.62	±462%	1,077	0.34%
Other Insulation*	933	21.88	±92%	1,097	1.99%
Air Sealing	1,173	(5.40)	±425%	1,095	-0.49%
Weatherization Overall	**1,252**	**107.82**	**±10%**	**1,094**	**9.90%**

*Statistically significant result

Table 3-4 shows the percentage of program participants who installed each measure along with our final evaluated savings estimates. In comparison to Table 3-2, the evaluated savings per household is significantly lower than that in the tracking system. This is most likely due to inaccuracy in either the calculation method or the tracking assumptions for baseline insulation and air sealing used to estimate savings. For further discussion on possible drivers of the observed difference in savings, see Section3.2. As discussed in detail in Section 2.3, these results are different from the billing analysis results shown above. They were adjusted as part of the engineering scaling process.

Table 3-4: Distribution of Natural Gas Weatherization Measures

Measure	Program Participants	Percent Installed	Evaluated Savings Per Household (therms/year)
Attic Insulation	1,888	60%	50.1
Sidewall Insulation	1,634	22%	65.4
Basement/Floor Insulation	707	41%	12.7
Other Insulation	1,171	56%	13.9
Air Sealing	1,501	71%	36.1
Insulation Overall	**2,186**	**76%**	**75.0**
Weatherization Overall	**2,188**	**76%**	**110.9**

3.1.1.2 Domestic Hot Water

Table 3-5 shows the distribution of hot water measures installed for customers with natural gas water heat, along with evaluated energy savings. DHW measures accounted for less than 1% of tracked total program gas savings.

Table 3-5: Distribution of Hot Water Measures for Gas Participants

Measure	Program Participants	Amount Installed per Participant	Evaluated Savings Per Measure (therms/year)
Showerheads	38	1.32 units	1.9
Faucet Aerators	6	1.16 units	0.8
Pipe Wrap	230	5.17 feet	0.6

3.1.1.3 Natural Gas Overall

Table 3-6 shows the billing analysis results for natural gas weatherization savings by measure type. Weatherization provides the vast majority of energy savings overall. The fact that the thermostat billing analysis result is so statistically significant is a notable finding, since few billing analyses have found statistically significant results for this measure in gas-heated homes.

Table 3-6: Billing Analysis Energy Savings Results for Natural Gas by Measure Group

Measure Group	N	Estimated Savings per Household	Std Err	Precision @ 90% Confidence	Pre-NAC per Household	Savings as Percent of Pre-NAC	Sample Tracking savings	Realiz-ation rate
Weatherization*	1,252	107.82	6.67	±10%	1,094	9.9%	327	33%
DHW	153	(9.63)	14.95	±255%	1,086	-0.9%	11	-91%
Thermostat*	500	30.18	8.83	±48%	1,148	2.6%	49	65%
Overall	**1,593**	**91**	**6.69**	**±12%**	**1,100**	**8.2%**	**274**	**33%**

*Statistically significant result

Table 3-7 shows savings overall for natural gas program participants. As discussed in detail in section 2.3, these results are different from the final evaluation results shown above. They were adjusted as part of the engineering scaling process. Some measures are shown here at the measure level, rather than at the household level.

Table 3-7: Evaluated Energy Savings for All Natural Gas Measures

Category	Measure	Natural Gas Savings (therms/year)	Units
Weatherization	*Weatherization Overall*	110.9	Household
	Insulation Overall	75.0	Household
	Attic Insulation	50.1	Household
	Sidewall Insulation	65.4	Household
	Basement/Floor Insulation	12.7	Household
	Other Insulation	13.9	Household
	Air Sealing	36.1	Household
Thermostats	Programmable Thermostat	10.1	Measure
Domestic Hot Water	Showerhead	1.9	Measure
	Faucet Aerator	0.8	Measure
	Pipe Wrap	0.6	Measure
Total	**Overall**	**90.7**	**Household**

3.1.2 Electric

This section includes electric savings results broken out by several groups, as well as overall results for program participants.

3.1.2.1 Weatherization

Table 3-8 shows the distribution of weatherization measures installed among different heating fuels and their accompanying evaluated electric savings. As expected, electrically heated homes save substantially more electricity per treated home as compared to oil and gas heated homes. It is interesting that oil weatherization saves more electricity than natural gas weatherization.

Table 3-8: Distribution of Weatherization Participants

Heating Fuel	Program Participants	Evaluated Savings Per Household (kWh/year)
Electric	124	782.2
Oil	685	96.9
Gas	2,039	72.4

Table 3-9 shows the number of participants that installed each weatherization measure, along with the tracking field labeled "Quantity," which represents either square footage or number of items installed, depending on the measure. This helps provide an explanation for why oil weatherization saves more electricity than gas weatherization. It suggests a higher amount of insulation installed, perhaps due to larger homes. Section 2.3 includes further discussion of this measure and the potential reasons for this difference.

Table 3-9: Average Quantity for Electric Customers

Heating Fuel	Measure	Participants	Average Quantity
Electric	Air Sealing	104	9
	Sidewall Insulation	14	539
	Attic Insulation	98	922
	Basement Insulation	42	514
	Insulation Other	470	19
	Overall	124	--
Oil	Air Sealing	733	10
	Sidewall Insulation	245	1,041
	Attic Insulation	661	1,034
	Basement Insulation	413	214
	Insulation Other	822	58
	Overall	685	--

3.1.2.2 Basic Install Package

This section presents the results of the basic package of measures installed in nearly every household in 2014. The two reasons for analyzing these measures together are 1) they were installed in the initial program site visit and did not require follow-up visits like some other measures, and 2) they were installed in almost every home and are very difficult to estimate savings for separately using billing analysis. Together these measures represent over 85% of program savings.

These measures were installed in the following percentages of homes, as represented visually in Figure 3-1.

- LEDs: 92%
- Refrigerator Brushes: 91%
- Smart Strips: 89%
- CFLs: 70%

Figure 3-1: Overlap of Four Measures in Basic Package (Percentages)

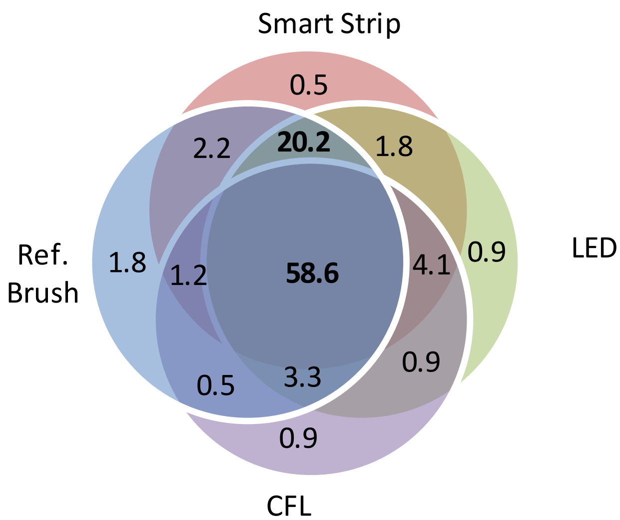


Table 3-10 shows the distribution of measures installed as part of the basic package, along with average savings resulting from the evaluation. As shown here, the evaluation suggests that LEDs saved much more than CFLs during the 2014 program year. This likely results from LEDs being installed in higher-use fixtures. See section 3.3 for further discussion. We also see that more than one Smart Strip is installed in the average home.

Table 3-10: Distribution of Basic Package Measures for Electric Participants

Measure	Participants	Amount Installed per Participant	Evaluated Savings Per Measure (kWh/year)
LEDs	8,206	8.2	23.6
CFLs	6,249	21.7	8.1
Smart Strips	7,890	2.1	21.6
Refrigerator Brushes	7,999	1.0	10.9

3.1.2.3 Domestic Hot Water

Table 3-11 shows the distribution of measures installed for participants with electric water heating, along with evaluated energy savings. This is a small group of measures within the context of overall program savings, representing less than 1% of program savings.

Table 3-11: Distribution of Hot Water Measures for Electric Participants

Measure	Participants	Amount Installed per Participant	Evaluated Savings Per Measure (kWh/year)
Showerheads	33	1.27 units	34.3
Faucet Aerators	11	1.64 units	36.6
Pipe Wrap	58	5.19 feet	33.3

3.1.2.4 Electric Overall

Table 3-12 shows the billing analysis results for electric savings. Notable findings include the statistically significant estimate for programmable thermostat savings and the much higher savings result for LEDs compared to CFLs. Other significant results include refrigerators and weatherization for electrically heated homes.

Table 3-12: Billing Analysis Electric Savings Results by Impact Group

Measure Group	N	Estimated Savings per Household	Std Error	Precision @ 90% Confidence	Pre-NAC per Household	Savings as Percent of Pre-NAC	Sample Tracking savings	Realization rate
CFL*	3,610	222.52	70.83	±52%	9,318	2.4%	1,045	21%
LED*	4,640	248.35	66.87	±44%	9,273	2.7%	410	61%
Other Lighting	192	270.14	166.59	±101%	9,601	2.8%	1,296	21%
Thermostat*	47	1,222.37	332.72	±45%	16,662	7.3%	1,524	80%
Wifi Thermostats	93	(55.47)	232.27	±689%	9,532	-0.6%	144	-38%
Refrigerator rebate*	54	579.03	302.84	±86%	9,925	5.8%	784	74%
DHW	44	316.98	334.29	±173%	10,359	3.1%	446	71%
Wx-Elec*	38	965.03	365.17	±62%	16,176	6.0%	1,558	62%
Wx-Oil	280	18.13	138.75	±1,259%	8,934	0.2%	336	5%
Wx-Gas	1,130	(128.05)	77.12	±99%	8,115	-1.6%	251	-51%
Overall	**4,965**	**434**	**42.40**	**±16%**	**9,274**	**4.7%**	**1,490**	**29%**

*Statistically significant result

Table 3-13 shows the overall evaluated savings for electric participants. As discussed in detail in section 2.3, these results are different from the final evaluation results shown above. They were adjusted as part of the engineering scaling process. Some measures are also shown here at the measure level, rather than at the household level as in the billing analysis tables.

Table 3-13: Evaluated Energy Savings for All Electric Measures

Category	Measure	Electric Savings (kWh/year)	Units
Weatherization	Electric Heat	782.2	Household
	Oil Heat	96.9	Household
	Gas Heat	72.4	Household
Thermostats	WiFi Thermostat	30.0	Measure
	Programmable Thermostat	214.6	Measure
Basic Install Package	Compact Fluorescent Light Bulbs	8.1	Measure
	LED Light Bulbs	23.6	Measure
	Smart Strips	21.6	Measure
	Refrigerator Brushes	10.9	Measure
Domestic Hot Water	Showerhead	34.3	Measure
	Faucet Aerator	36.6	Measure
	Pipe Wrap	33.3	Measure
Other	Refrigerator Replacement	460.8	Measure
	Light Fixtures	18.8	Measure
	Outdoor Fixtures	45.0	Measure
	Torchieres	40.1	Measure
Total	**Overall**	**385.8**	**Household**

3.1.3 Oil Weatherization Savings

Table 3-14 shows oil savings for weatherization participants with oil heating.

These savings were calculated based on the natural gas weatherization savings. The formula used to calculate these results are as follows:

$$Wx\ Oil\ Savings = Wx\ Gas\ Savings\ \times \frac{Wx\ Oil\ Heat\ "Quantity"}{Wx\ Gas\ Heat\ "Quantity"} \times 0.10\ MMBtu\ Per\ Therm$$

Using "Quantity" as a scalar value to represent the different characteristics of oil-heated homes on average, this formula results in the Oil savings estimate shown here. This formula was applied to each measure group separately, and then they were combined to result in the total program savings

Table 3-14 shows savings for weatherization of homes with oil heat. The Ex Ante savings came from the BO Reports, which include 19,843 total gallons of oil saved for 838 homes, or 23.7 gallons per home.[22]

[22] This assumes that oil savings was calculated as a deemed value which could be obtained by dividing the number of homes into the total savings. The electric tracking data for oil weatherization participants had a number of duplicate deemed savings lines, an issue which was corrected in 2015. The stated 838 homes was reduced to 685 in the table for this reason. It is also not clear why such a low deemed savings value of 23.7 gallons per home would be used.

Table 3-14: Annual Ex Post Gross Savings by Measure for Oil

Measure	Partici-pants	Ex Ante Savings (MMBtu/Year)	Ex Post Savings (MMBtu/Year)	Units	Realization Rate	Source
Weatherization Overall	685	23.7	14.0	Household	59%	ENG

3.2 Tracking Data Review

As a part of this evaluation, DNV GL was asked to perform a review of the tracking data for natural gas weatherization as well as a review of the RISE program database.

There were two reasons for this review:

- Realization rates for this evaluation are low for natural gas weatherization.
- As shown in Table 3-15, given the differences in R-values recorded in the tracking data and those printed in the previous evaluation report, the tracking savings estimates should be lower per household. However, the estimates were actually higher.

Table 3-15: Comparison of Natural Gas Weatherization Values and Savings[23]

Category	2014 Tracking Data					2012 Study				
	Homes	Heated Floor Area (ft2)	Pre-R-Value	Post-R Value	Savings/Home	Homes	Ft2 of Insulation	Pre-R-Value	Post-R Value	Savings/Home
Air Sealing	1,922	1,729	--	--	107	353	--	--	--	87
Sidewall Insulation	709	1,508	0.0	13.0	182	146	1,257	3.7	13.2	110
Attic Insulation	1,637	1,739	6.7	29.2	184	302	1,017	10.6	44.3	87
Basement Insulation	1,172	1,686	0.0	20.3	38	132	579	6.6	18.9	35
Insulation Other	2,088	1,725	--	--	14	--	--	--	--	--

An initial review of the tracking data for major measures that make up the bulk of natural gas program savings revealed that savings are largely calculated in accordance with the InDemand calculations provided. Savings were calculated in accordance with formulas for greater than 95% of measures under each of the major categories. Those which did not match were not dramatically different than predicted by the calculation, and may have represented deemed savings which were applied for specific measure codes.

[23] Note that "Heated Floor Area" and "Ft2 of Insulation" are not directly comparable. The 2014 data does not contain a field which represents ft^2 of insulation installed. "Quantity" contains this value for some measures, but the sum total of "Quantity" produces values that are not in a reasonable range given the average household size.

DNV GL also performed a review of the RISE data in an attempt to see if errors might have been made in data transfer. This review took place, but the result is primarily the finding that RISE's data cannot be consistently compared directly to National Grid tracking data. It matches up in a lot of cases, but not all.

Here are the reasons why:

- In 2014, RISE did not keep their savings calculations consistent or up to date with National Grid savings calculations. This is because the RISE database was not intended to develop savings estimates, but simply to collect the inputs to those calculations which were then performed by National Grid. We understand that this was changed in 2015.
- When errors are found (with regard to R-values, square footage, etc…) in RISE's quality control reviews, they are corrected in the "upload packages" which are provided to National Grid for incorporation into the tracking data. These corrections are not backwards-applied to RISE's data, and so there are many discrepancies.
- Many homes in the RISE data showed multiple lines which used the same exact measure code. For example, one portion of an attic may have been insulated with R-30 insulation, and another part insulated with R-30 as well, perhaps at a later date. This leads to multiple lines in the RISE data where a single line may appear in the National Grid data.
- RISE does not attempt to record R value consistently for measures which have deemed savings.

For these reasons, we chose not to attempt to reconcile data from the RISE database to the National Grid database.

3.2.1.1 Result of Tracking Data Review

After completing the tracking review, we are still not confident as to the reason(s) why savings shown in the tracking data do not accurately represent reality.

The most likely reason for the discrepancy in our opinion is that the tracking data does not effectively or consistently capture the levels of existing insulating value provided by previously installed insulation and building materials.

For most insulation measures, the tracking data shows zero insulation in the pre-installation condition. While this may be common, it is certainly not ubiquitous. Part of the reason for this issue may result from a program change which occurred in 2012. Previous to this, RISE collected data on baseline insulation while afterward subcontractors began collecting it.

The calculations attempt to account for this to a point by including baseline R-values, shown in Table 3-16, which are intended to account for the insulating value provided by building materials besides insulation. Whether these calculations reflect the average insulating value provided by non-insulation building materials is possible. However, they do not accurately reflect the combination of building materials and insulation in the baseline condition based on the results of our billing analysis. We did not attempt to formally back-calculate insulation values which would have produced the billing analysis results. However, a back-of the envelope calculation suggests that baseline R-values of 12, 9.5, and 14 for attic, sidewall, and basement/floor insulation provide an approximate order of magnitude for a calculation that would produce more-accurate estimates.

Table 3-16: Tracking Baseline R-Values

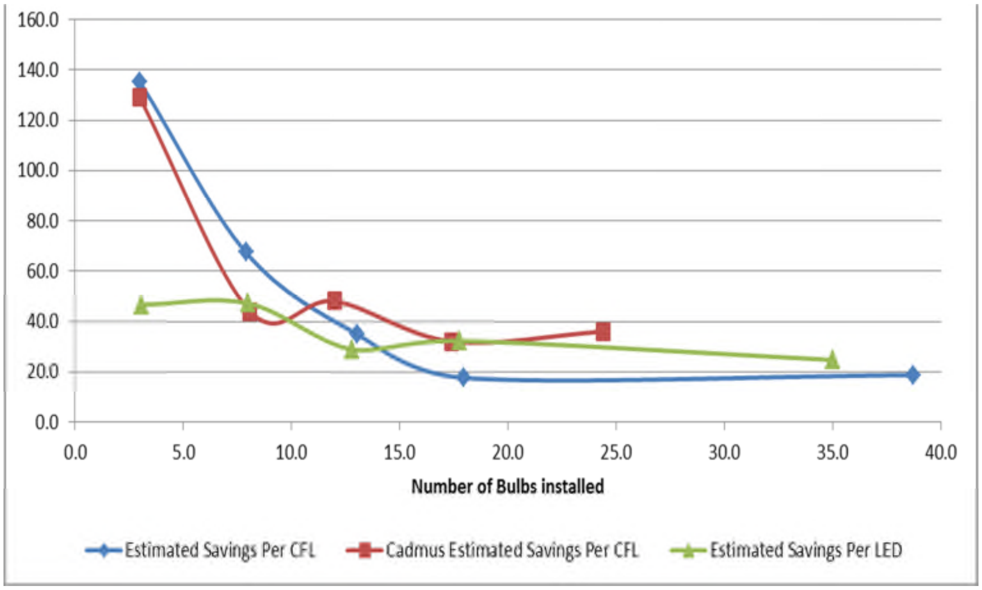
Measure	Baseline R-Value
Attic Insulation	3.36
Basement Insulation	6.16
Sidewall Insulation	6.65

3.3 Lighting Per-Bulb Analysis

The purpose of this section is to show the savings associated with lightbulbs, as a function of the number of bulbs installed in the house. A similar analysis was performed in the previous round of evaluation, and was recreated and expanded here. While none of the results are statistically significant, they are informative and useful for program design.

We first performed a comparison of our results with the results of the 2012 evaluation using what we think are similar methods to what were used in that study. Figure 3-2 shows the comparison.

Figure 3-2: Comparison with 2012 Study on Savings per Bulb

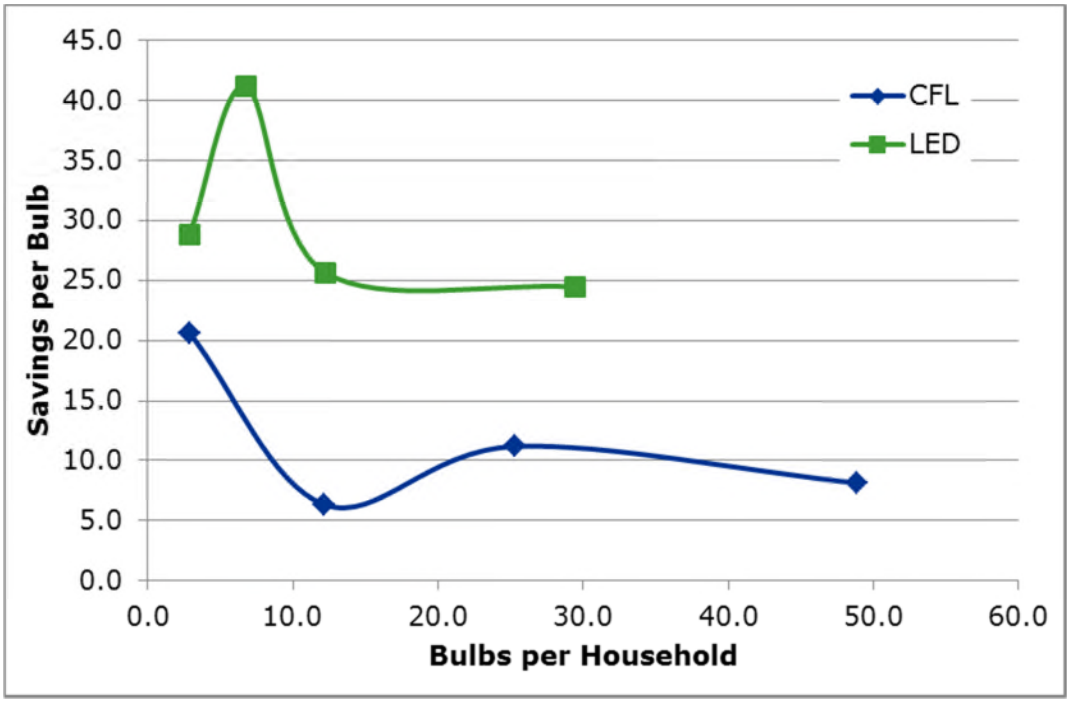


As shown here, CFL savings per bulb is nearly identical to that found in 2012.

However, after further discussion and review, we determined that this method includes a significant limitation in that it does not exclude the results of other measures. In other words, much of the variation in savings by number of bulbs is due to the fact that most households installed other measures in addition to lightbulbs, which artificially inflate the savings for small numbers of bulbs.

Figure 3-3 shows an updated set of results which uses a different billing analysis specification that allows us to more-accurately separate out the influence of other measures.

Figure 3-3: Savings by Numbers of Bulbs



As shown here, the curve is less sharply downward and less clean. This reflects the reality of billing analysis, in which results rarely show clean and smooth patterns, and curves which look too good to be true usually are. However, the trend is generally clear that installing smaller numbers of bulbs saves more energy per bulb. One drop-off appears to be somewhere in the range of 5-10 bulbs.

Table 3-17 shows the data behind Figure 3-3. Rows in grey are not statistically significant and should be given less trust. Note that the results shown here are the result of a separate billing analysis from those shown in Section 3.1.2.2. The reason for the difference is that results in the other section had to be adjusted (reduced) to account for savings from measures which did not have statistically significant billing analysis results.

Table 3-17: Savings by Numbers of Bulbs

Groups	Bins	Percent of Participants	Savings per Participant	Average Number of Bulbs	Savings/ Bulb	Precision
CFL	1 to 5	20%	68.1	2.9	20.7	246%
	6 to 20	37%	93.8	12.2	6.3	150%
	21 to 30	18%	307.4	25.3	11.2	57%
	greater than 30	25%	417.7	48.9	8.1	38%
	Average	**100%**	**207.0**	**21.7**	**10.5**	--
LED	1 to 3	53%	99.9	2.9	28.8	120%
	4 to 9	24%	290.0	6.7	41.2	51%
	10 to 15	10%	326.5	12.2	25.6	60%
	greater than 15	13%	735.6	29.5	24.5	24%
	Average	**100%**	**251.6**	**8.2**	**30.9**	--

3.3.1 Forward-Looking LED Results

The results shown in the report up till this point are designed to reflect savings achieved in 2014. However, the program approach changed starting in late 2014 to start installing more LEDs than CFLs, and eventually CFLs were phased out.

The LEDs bulbs per home value is likely to increase from 8.2 bulbs per home from 2014 to something closer to the total (LED and CFL) bulbs per home value from the October-December period of 2014 (when LEDs became more prevalent), of 20.0 bulbs. For this reason, the 2014 savings values may not represent the LED measure going forwards.

Table 3-18 shows the LED savings per-bulb from Table 3-17, savings values adjusted by the engineering adjustment ratio used for LEDs in the 2014 results,[24] as well as the percent of bulbs installed in each bin during October-December 2014. Finally, it shows the weighted average savings per bulb from this period of 20.3 kWh per LED bulb.

Table 3-18: Engineering-Adjusted 2014 Oct-Dec. Per-Bulb Savings

Bins	Savings/ Bulb	Engineering Adjusted Value	Percent of Bulbs Installed Oct-Dec.	Weighted Average Savings
1 to 3	28.8	22.4	1%	20.3 kWh / Bulb
4 to 9	41.2	32.1	9%	
10 to 15	25.6	19.9	9%	
greater than 15	24.5	19.1	82%	
Average	**30.9**	**24.0**	**100%**	

[24] This value, 0.778, was used to reduce the realization rate for LEDs in order to create space for non-statistically significant measures.

We recommend that the program consider using the 20.3 kWh per bulb as a starting point for developing savings for LED bulbs in 2017.

While this period does represent the most-applicable portion of 2014, it is not perfectly representative of the current program design which does not include CFLs at all. The 2014 program year was an unusual one because of the high numbers of CFLs installed in combination with LEDs even in October-December, which probably produced some level of confounding effect on savings estimates.

If the program design—especially with regard to the numbers of LED bulbs installed per home—varies significantly from the design used in late 2014, another number such as the Massachusetts Market Adoption Model may be appropriate to substitute.

Because of the limited applicability of this value, we recommend updating it at some time in the future, either through literature review, an update to the billing analysis with more recent data, or both. This could best be completed using 2015 data which is far more LED-dominated than 2014, or National Grid could choose to wait to perform a billing analysis on a year in which only LEDs were installed.

If this does not occur, we recommend using the baseline market adoption model (MAM) from the Massachusetts saturation study,[25] which will have updated values this fall. However, we recommend calibrating the MAM by adjusting the baseline assumption (and therefore the delta-watts values) so that savings for 2014 match the result of this study (20.3 kWh per LED bulb) rather than the values determined for Massachusetts. The trajectory of residential LED market adoption from the MAM could still be applied, but the adoption curves must be adjusted so that they match the current lighting installed base in Rhode Island based on this study.

3.3.2 LED Savings for Small Bulb Count

After early results (see Figure 3-2) showed a smaller amount of savings for small number of LEDs than for CFLs, DNV GL engaged in discussions with National Grid and RISE Engineering about this issue.

RISE offered one suggestion as to the reason that LED savings might be lower than CFLs for small bulb quantities: for much of 2014 LEDs may have been installed more often in candelabra-based fixtures than they have been since. The implication was that these specialty-type bulbs might have fewer hours of use than standard A-Lamp applications. Table 3-19 and Table 3-20 call this theory into question, as the quantity of different bulb types installed across the two years are similar.

Table 3-19: LED Bulb-Type Proportions in 2014-15 Compared

Bulb Type	Avg. Watts	Counts			
		2014		2015	
A-Lamp	11.0	35,755	53%	113,747	40%
Decorative	6.7	17,915	27%	76,021	27%
Reflector	12.1	13,844	21%	95,386	33%
Total		**67,514**		**285,154**	

[25] *Lighting Market Assessment and Saturation Stagnation Overall Report*. Prepared by The Cadmus Group for the Electric and Gas Program Administrators of Massachusetts, August 2015.

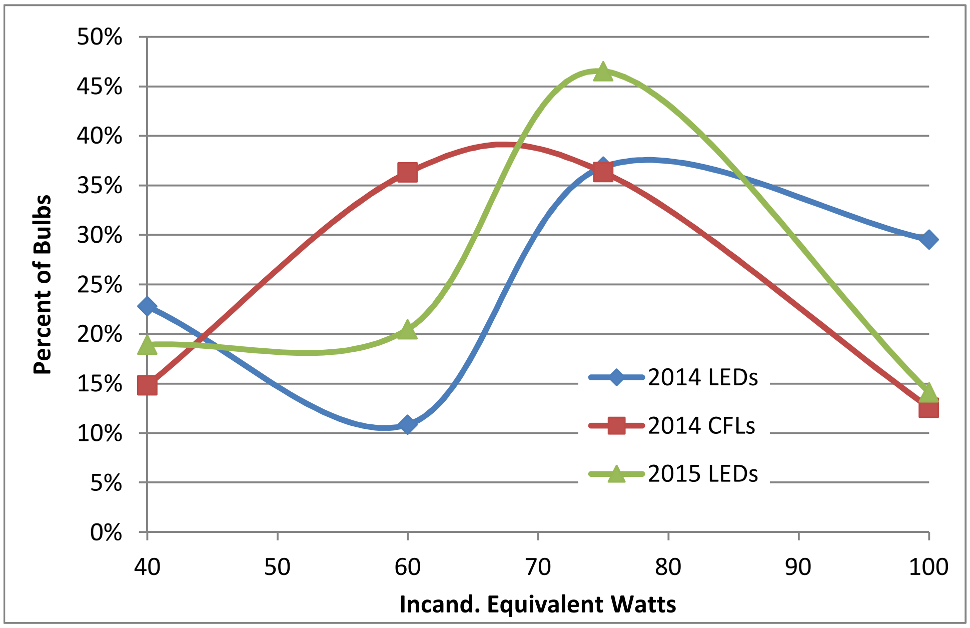
Table 3-20: Candelabra Bulb Types Installed 2014-15 Compared

Year	Month	3.5 W CANDELABRA	3.5 W CANDELABRA	5W Torpedo Cand 1100.0181	2.5W LED Diamond Candle 1316
2014	3	0	0	0	0
	4	0	0	0	0
	5	77	0	0	0
	6	896	20	0	0
	7	5,893	57	0	0
	8	1,978	123	0	0
	9	670	0	246	0
	10	55	0	2,284	0
	11	0	0	727	0
	12	0	0	2,353	0
2015	2	0	0	3256	0
	3	0	0	2,956	0
	4	0	0	5,960	0
	5	0	0	6,979	0
	6	0	0	2,883	0
	7	0	0	6,365	0
	8	0	0	4,888	50
	9	0	0	5,306	216
	10	0	0	4,083	109
	11	0	0	3,594	176
	12	0	0	5,647	141

3.3.3 Bulbs by Wattages

Figure 3-4 and Table 3-21 show the results of an analysis into the numbers of bulbs installed at various wattages during the 2014-2015 program years. This analysis was initially performed to help understand the early (later superseded) per-bulb billing analysis results. However the information provided is still useful for program understanding and so is included here.

Figure 3-4: Bulb Categories 2014-15[26]



As shown here in Figure 3-4, on average LEDs and CFLs of similar lumen output (similar incandescent equivalent wattage) were installed in both 2014 and 2015, with one exception. This exception is that 60 watt equivalent bulbs were less popular for LEDs than for CFLs in both years.

Table 3-21: Baseline Bulb Wattages 2014-15[26]

Baseline Group	2014 LEDs	2015 LEDs	2014 CFLs
100 W replacements	30%	14%	13%
75 W replacements	37%	47%	36%
60 W replacements	11%	20%	36%
40 W replacements	23%	19%	15%
Wt. Avg. Baseline Watts	45.3	46.8	48.5
Wt. Avg. Installed Watts	8.9	9.4	17.2
Wt. Avg. Delta Watts	**36.4**	**37.4**	**31.4**

Table 3-21 shows the weighted average baseline and delta watts values for the Rhode Island EnergyWise program in 2014-2015. This is provided to help calibrate, or establish a starting point for, the MAM to be used in applying energy savings going forwards.

[26] Baseline and equivalent wattages based on the following spreadsheet, currently cited in RI TRM: *NMR Group (2012). Baseline Sensitivity Analysis Spreadsheet, Three-Year Planning Version. Prepared for the Massachusetts PAs*

4 CONCLUSIONS AND RECOMMENDATIONS

As mentioned above, the savings estimates produced by the billing analysis are significantly lower than that predicted by the tracking savings. The known reasons for this are as follows:

- **CFLs and LEDs**: Tracking savings for CFLs and LEDs were based on data extrapolated from the 2012 evaluation per-bulb analysis. These results appear not to be applicable going forwards, as discussed in section 3.3. Part of the reason may be that the average number of bulbs in 2012 was 9, while the average number in 2014 was 23, so the extrapolation may have been of limited applicability to the new program design. In 2015, the Energy Efficiency Resources Management Council consultants asked National Grid to switch the CFL and LED lighting assumptions to the Massachusetts (MA) Market Adoption Model which are based on MA programs and assumptions instead of Rhode Island. This resulted in a value which this billing analysis found not to be very applicable to Rhode Island. We suggest that the results of this evaluation are more applicable, and should be used going forwards, at least in 2017. It would also be possible to calibrate the Market Adoption model based on the results of this evaluation, as discussed in section 3.3.
- **Gas Weatherization**: Weatherization savings for natural gas heated households were not well reflected by the calculations used to produce the tracking data. We explored the reasons for this in the tracking data as well as the RISE tracking database, and were not able to find a definitive answer. The potential unexplored reasons for this issue are as follows:
    - The baseline level of insulation in homes is not accurately recorded in the tracking data. For most measures, the baseline level is reported as zero, which is probably unrealistic.
    - The baseline R-value assumptions included in calculations may not accurately reflect the actual baseline R-value associated with existing building materials and insulation.
- **Refrigerators**: It is well known throughout the energy efficiency industry that refrigerator replacement savings are decreasing every year as older refrigerators built prior to manufacturing standards become rarer. The realization rate for refrigerators reflects this.

Realization rates also have implications for cost-effectiveness. While they do not correspond directly, lower realization rates can have a downward effect on cost-effectiveness. This effect is currently being experienced at residential retrofit programs around the country , and program managers are wrestling with how to continue to run residential retrofit programs that are borderline cost-effective.

There are a number of reasons one might want to continue with a program like EnergyWise even if it were not cost-effective using the standard Total Resource Cost (TRC) test, including the following:

- Residential retrofit programs provide durable benefits to participants and to society in addition to energy savings, which are not reflected in the TRC. These include providing economic growth for Rhode Island by primarily hiring contractors based in the state,[27] as well as carbon reductions.
- Home weatherization programs reach customers at important milestones in their lives such as when they move or begin major home renovations. Because of this, they serve as an entry point for new participants into the program, which increases the odds that they will participate in other programs in the future.

---

[27] Analysis of Job Creation from 2015 Expenditures for Energy Efficiency in Rhode Island by National Grid, Pergrine Energy Group (2015): http://www.ripuc.org/eventsactions/docket/4527-NGrid-YrEndRept(5-2-16).pdf

- Programs like EnergyWise take a long time to ramp up and down, and the decision to stop running such a program is not one that can be reversed quickly. Many trade allies depend on EnergyWise for their business, and if they left this sector many of the most qualified could not or would not re-enter if the program were to restart.[28]

We recommend that the program administrator consider the following in the coming years of program implementation:

- Adopt the deemed savings estimates produced by this evaluation for use going forwards.
- Update the approach used to estimate energy savings for natural gas weatherization in the tracking system. This can include updating the prescriptive savings formulas used to match results from this evaluation, or a change to a deemed savings estimate.
- Consider using the results from this effort as a starting point for developing savings for LED bulbs in 2017. The numbers reported here are representative of savings from the portion of the 2014 program year that is likely to be most similar to 2017. However, if the program design—especially with regard to the numbers of LED bulbs installed per home—varies significantly from the design used in late 2014, another number such as the Massachusetts Market Adoption Model may be appropriate to substitute. We also recommend that National Grid consider in 2017 whether and how to update the savings estimates for LEDs going forwards. This study did not look into the issue of how well the late-2014 results represent program activity in 2015 and 2016. The fact that most households even in late 2014 installed both LEDs and CFLs suggests that they are not a perfect representation of a future in which only LEDs are installed. Options for updating savings estimates could include a review of tracking data from 2015-16, a literature review of results from other states, or an update to the billing analysis using 2015 data.
- In the future, we recommend that billing analyses include all measures installed by participants who began their participation in the analysis year, including those whose participation spanned multiple years, to the extent possible. At least for natural gas, we found that multi-year participants install more measures overall than single-year participants.

[28] http://blogs.dnvgl.com/energy/realizing-the-promise-of-wh-retrofits

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.