2013 NATIONAL GRID MULTIFAMILY PROGRAM

GAS AND ELECTRIC IMPACT STUDY

National Grid, Eversource, Cape Light Compact, Unitil, Columbia Gas, Berkshire Gas

October, 2016

Table of Contents

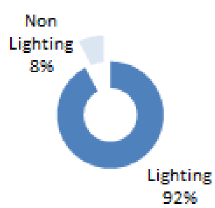
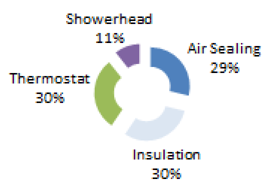
Table of Figures

Table of Tables

1 EXECUTIVE SUMMARY

The Mass Save® Multifamily Retrofit Program is a direct installation program that promotes both electric and gas energy efficiency measures. The goal of this study is to provide 2013 program level (Residential Multifamily) realization rates for both electric and gas overall and provide disaggregated results where appropriate. Electric and gas tracking savings are summarized below and reflect program activity in the 2013 program year. Electric savings are dominated by lighting measures while gas savings have a more even distribution that includes thermostats, air sealing and insulation.

ES Table 1: Tracking Savings Summary

	Electric	Natural Gas
Number of Facilities	268	128
Total Annual Claimed Savings	14,571,847 kWh	444,354 therms
Savings Summary		

Methods

We used a two-stage, premise-level, difference-of-differences modelling approach for energy consumption analysis using a dataset combining consumption, weather, and participation and other premise and customer-specific characteristics information. This approach estimates gross energy savings and relies on a comparison group consisting of future participants to control for non-program related change. This evaluation effort was preceded by an initial effort to evaluate Columbia Gas, Eversource and National Grid based on a different data source. Our inability to confidently roll up account and premise level activity to a facility became insurmountable in that effort, which led to this study. The data in this study relies nearly exclusively on data directly from National Grid and was accompanied by stages of review to ensure the representation and adequacy of the data to support the billing analysis.

Results

Aggregate analyses of both electric and natural gas impacts were performed that included an approach that rested upon facility level and one built up from the account level. We summarize the overall savings for each estimate based on the facility level analysis in ES Table 2. The Multifamily Program is producing electric savings, though much less than estimated in the tracking system. Our estimate of savings from the 2013 program year is 3,558,796 kWh with a precision of ±49.3 at the 90% confidence interval. This result provides a realization rate of 24.4%. We found no substantial difference in results when analyzed at the premise level or when examined by facility size (number of premises in each facility) or housing type (apartment vs condominium), though we found participants with commercial billing rates experienced greater savings in absolute terms as well as percent of consumption than participants with residential rates.

Our final estimate of program level natural gas impacts is 383,129 Therms, which does not include interactive effects. This result is accompanied by a realization rate of 86.2% and a precision of ±64.1% at 90% confidence interval. In the body of the report we include gas savings and realization rates that incorporate interactive effects to illustrate the influence of interactive when customers install program lighting and gas measures at the same time. We also analyzed program impact by separating premises based on sector (commercial vs residential), ownership type (apartment versus condominium), and size (5-20 and >20 units). The tracking savings estimate for commercial bill rates had a considerably higher realization rate (127%) and savings as a percent of consumption (12.4%) than savings estimated for residential (38% and 1.6%, respectively). We also found results vary when facilities examined by ownership type, though not as significantly, with apartment and condominium realization rates of 108.8% and 68.5%, respectively.

ES Table 2: Summary of Results

	Electric	Natural Gas
Estimated Savings	3,558,796 kWh	383,129 Therms
Realization Rate and Precision	24.4% @ 90% ±49.3%	86.2% @ 90% ±64.1%

Recommendations

The following recommendations rest upon the activities undertaken as part of this study. Some of these recommendations may already be planned or underway as part of ongoing program improvements.

1. Regularly enter the physical location of installed lighting, which would allow optimal use of the regional HOU study to inform the hours of use estimates in the tracking system.
2. Given the difficulty in observing lighting savings due to its low savings signature, consider other evaluation methods in subsequent studies of this program when predominate savings is from lighting.
3. Consider performing a small sample of inspections to ensure accurate tracking of measure locations, quantities and pre-existing conditions (when possible), along with verification of account to facility mapping.

2 INTRODUCTION

DNV GL, as a subcontractor to The Cadmus Group in the Residential Program Evaluation area, is pleased to submit this report to the Massachusetts Program Administrators (the PAs) and the Energy Efficiency Advisory Council (EEAC) consultants. This report provides the electric and natural gas impacts from the Mass Save® Multifamily Retrofit Program's (Multifamily Program) residential channel as determined through billing analysis methods.

The goal of this study is to provide program level (Residential Multifamily) realization rates for both electric and gas overall for 2013 and provide disaggregated results where appropriate. We used a two-stage, premise-level, difference-of-differences modelling approach for energy consumption analysis using a dataset combining consumption, weather, and participation and other premise and customer-specific characteristics information. This approach estimates gross energy savings and relies on a comparison group consisting of future participants to control for non-program related change. DNV GL led this study, although there was communication among other residential evaluation team members as data was gathered to support the study.

The team performed the core analytics for this study from March through July 2016 with a focus on National Grid electric and gas participants from 2013. We note that this study was preceded by a feasibility study and an attempted gas and electric billing analysis for three sponsors, including National Grid, Eversource, and Columbia Gas. This previous effort was founded upon data provided by the residential evaluation contractor with some inherent limitations in its use, including, among others, an inability to confidently roll up account and premise level activity to a facility.

Following discussions with a working group comprised of several program administrators and an EEAC representative, it was determined that the issues and challenges encountered in the account level analysis of that initial study warranted a change in approach. This new approach became the impetus for this current study, which focuses on a facility level billing analysis for National Grid. National Grid is the ideal candidate for this effort as they carry facility level identifiers on all unique accounts located within the treated facility. Building up to a facility level allows a better understanding of which facilities to include in the analysis. We provide a memo summarizing the initial effort with its latest results as Appendix B to this report. The remainder of this report contains the results of National Grid electric and gas multifamily participants, and includes several key data sets provided directly from National Grid.

3 BILLING AND TRACKING DATA ASSESSMENT

This section presents participant and comparison group matching work, selection and summary of the tracking system savings estimates for each. The following section summarizes electric data followed by a section on gas data.

3.1 Electric Tracking and Billing Data Summary and Matching

This section reviews the participant and comparison group tracking and billing data activity, completeness, and characteristics, including match rates.

3.1.1 Participant Group

DNV GL received tracking information for 2013 National Grid multi-family electric participants from Cadmus. The 2013 tracking data contained facility-level savings, installation dates, and measure information that had been distributed evenly to the account level. We rolled the account-level tracking data back up to the facility-level and confirmed aggregate and measure level savings with National Grid. There are 269 unique multi-family facilities in the tracking dataset received from Cadmus with total electric savings of 14,572 MWh.

We acquired billing data for 2013 electric participants for the period of 2011 – 2015 from National Grid. The billing data is at the premise-level and contained information such as interval begin and end dates, total electricity consumption during that period, rate code, and description of the reading type. There were 417 unique facilities in the billing dataset.

We then checked the status of billing data completeness for each premise within a facility. It is important to see if a premise contains enough pre/post-installation period billing data for the electric impact analysis. We specifically checked if a premise had at least 12 billing intervals of pre- and post-installation data, whether a premise had any zero usage reads, and if a premise had a usage spike. These conditions are discussed further below.

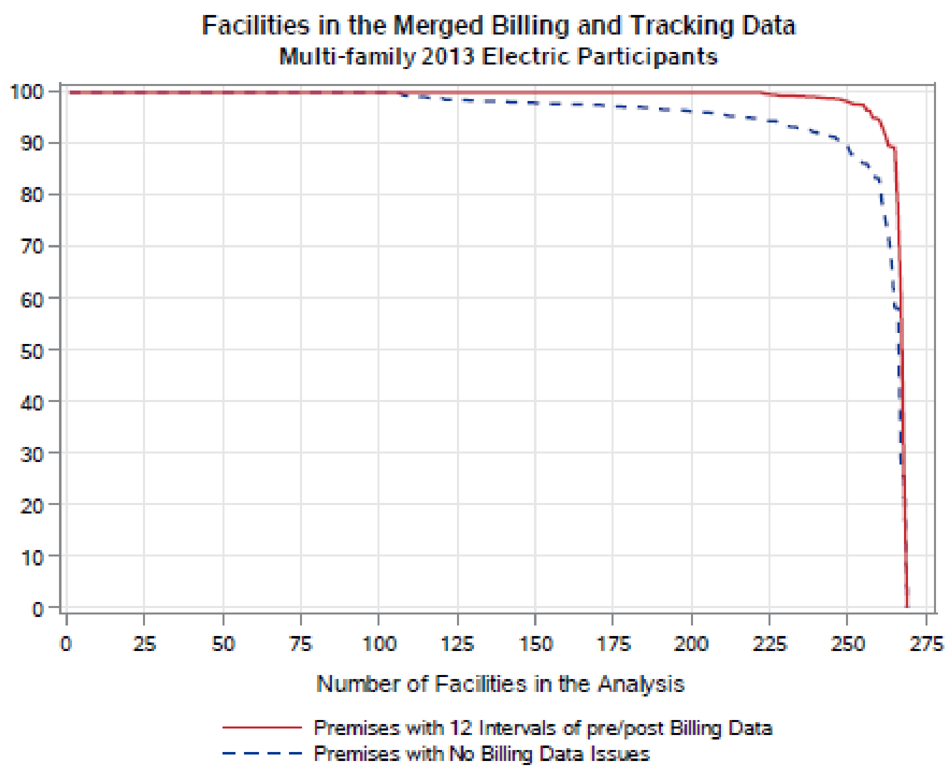
To assess billing data completeness, we checked if each premise had the electric billing data of the 27 months surrounding the installation completed date in a facility. Specifically, we flagged premises if they had at least 12 billing intervals of pre-installation period and 12 months of post-installation billing interval data after considering the 3 months prior to the installation date as the blackout period. Premises were flagged as having zero usage if they had any single billing interval usage of 0 kWh. Premises were identified as having a usage spike if there was at least one billing interval daily usage that was greater than three times the average usage of two prior (lagged) billing interval daily usages and average of two future (leads) billing interval's daily usage.

We also rolled up billing interval data if the read type was ‘final’, which indicates the final reading of one account before a new billing account is opened at the same premise. Among different read types available in the billing dataset, we noticed that billing intervals were shorter for ‘final’ read types. Moreover, the bill start and end dates of the majority of premises within the facility were identical for other read types. At the same time, these read types were causing usage spikes and drops in the billing dataset. We rolled final and estimated read types to the subsequent regular read types in order to have similar bill interval days. As a result, we were able to decrease number of premises with usage spikes and zero usage by 50% as compared with the premises with similar issues in the original billing data.

As a next step, we matched facilities that were available in both the tracking and billing dataset. The facilities available in the tracking dataset matched entirely with the billing dataset, resulting in 269 facilities with both tracking and billing information. The remaining 148 facilities were only in the billing dataset and were low-income facilities. The participant group for this billing analysis was limited to the 269 facilities from the tracking system.

Figure 1 contains the number of treated facilities (X axis) with the percentage of their premises (Y Axis) with billing data during the analysis period for 2013 multifamily participants. There are 269 facilities represented. The solid red line shows the percentage of premises that have at least 12 billing intervals in the pre-installation period and 12 months of post-installation billing interval data after considering the 3 months prior to the installation date as the blackout period. There are 262 facilities where at least 90% of their premises have 12 months of pre and post billing data. The dashed blue line shows the percentage of premises that have at least 12 months of billing data in the pre and post periods, no zero reads and no usage spikes. A total of 249 facilities have at least 90% of their premises meeting these conditions.

Figure 1: Percentage of Participating Premises within a Facility with Complete Billing Data

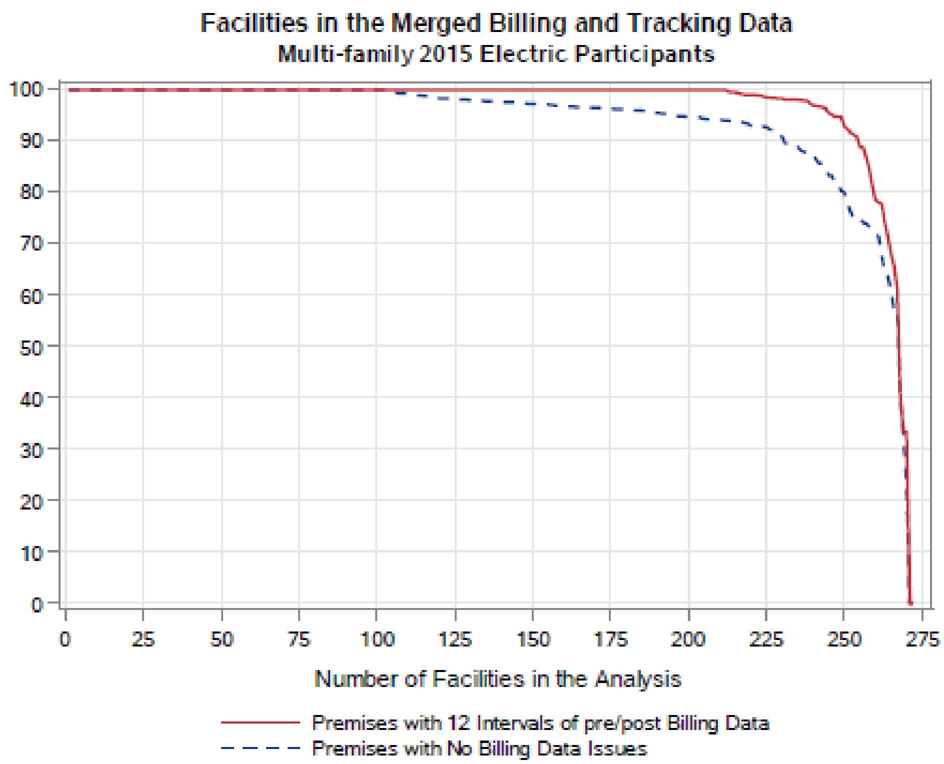


3.1.2 Comparison Group

We conducted a similar data assessment of the multifamily electric participants of 2015, which form the comparison group of the impact evaluation. Using 2015 participants as the comparison group allows us to have 27 billing interval data surrounding the pre/post periods of 2013 participants that are still prior to the installation date of the 2015 installing facilities. DNV GL received both tracking and billing datasets of 2015 multifamily facilities from National Grid. Like the 2013 participant group, the tracking data was at the facility-level, whereas monthly billing information is at the premise-level. There were 506 multi-family facilities available in the 2015 tracking and billing dataset. Out of the total 506 facilities, 101 had participated in prior years and thus were removed from the comparison group. Like the participant group, we also excluded 135 facilities from the comparison group sample who were categorized as "low income" type. As a result, the final sample in the comparison group consisted of 270 facilities.

Next we looked at the billing data status of matched tracking and billing data of multi-family facilities participating in 2015 (i.e., the comparison group). Figure 2 is laid out the same as Figure 1. There are 254 facilities where at least 90% of their premises have 12 months of pre and post billing data. A total of 230 facilities have at least 90% of their premises with 12 months of pre and post billing data that do not have a usage spike, or having zero reads.

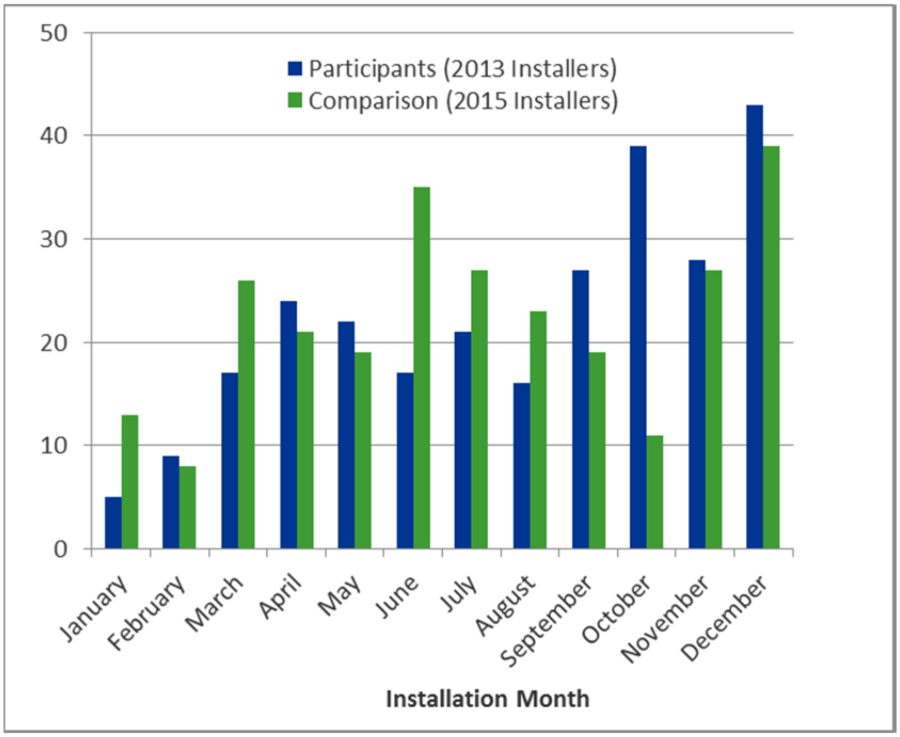
Figure 2: Percentage of Premises within a Facility with Complete billing data (Comparison Group)



As described later, in both the base electric and gas billing analysis, we include all premises that have at least 12 intervals of billing data (i.e., the premises represented by the red line). Following that base analysis, we then exclude premises with different billing issues (e.g., usage spikes, short bill intervals, and long analysis period, etc.) to check the consistency of results and to compare each model's saving estimates with the base model.

Figure 3 presents the number of electric participating and comparison group facilities treated by month. The comparison group had substantially more facilities participate in June while the participant group had more facilities participate in October. Both groups had upward participation trends in November and December.

Figure 3: Profile of Participant and Comparison Group Activity by Month



3.1.3 Final Electric Data Disposition

DNV GL also looked at the status of electric billing data at the premise-level of matched facilities. Table 1 shows the distribution of premises with different billing data issues for both participant and comparison group facilities. As suggested above, we have an overwhelming percentage of premises with good and complete billing data in both groups. In the impact evaluation, we start with premises of both groups that have at least 12 months of pre- and post- billing interval data including premises with usage spike and zero usage. We then perform analysis by excluding premises that have usage spikes and zero usage separately. Looking at the different results that includes subset of full sample allows us to check the consistency of the results. More details on this are provided in the results section.

Table 1: Billing Data status of Premises that belong to Matched Facilities

Premises with 12 pre/post billing interval data	Premises with Usage Spike	Premises with zero Usage	MF 2013		MF 2015	
			Premises Count	Percent of Total	Premises Count	Percent of Total
Yes	No	No	24,597	97.0%	15,988	94.9%
No	No	No	86	0.3%	345	2.0%
Yes	No	Yes	400	1.6%	287	1.7%
No	No	Yes	28	0.1%	62	0.4%
Yes	Yes	No	186	0.7%	102	0.6%
No	Yes	No	1	0.0%	2	0.0%
Yes	Yes	Yes	54	0.2%	60	0.4%
No	yes	Yes	7	0.0%	10	0.1%
		Total	25,359	100.0%	16,856	100.0%

3.1.4 Electric Tracking Data Summary

Table 2 shows the summary statistics from the tracking datasets for both participant and comparison groups. There are 268 facilities in the participant group with total claimed tracking savings of 14.6 million kWh. The savings attributed to lighting energy efficiency measures constitute of 92.2% of the total claimed savings. Roughly 5% of tracking savings was from thermostats and smart strips. The savings claimed in dwelling versus common spaces[1] are 57.9% and 42.1% of the total claimed savings, respectively.

The total claimed savings from the comparison group is 46.5 million kWh from 270 multi-family facilities. Among the total savings, lighting measures make up 83.0% of savings. The energy efficiency measures installed in the dwelling spaces constitute 40.3% of total claimed savings, whereas the measures installed in public spaces represent 59.7% of the total claimed savings.

Table 2: Tracking Data Summary

Description	Participant Group (MF 2013)	Comparison Group (MF 2015)
Number of Facilities	268	270
Number of Premises in the Facilities	25,237	16,437
Total Annual Claimed Savings (kWh)	14,571,847	46,470,977
Percentage of Lighting Savings Claimed	92.2%	83.0%
Percentage of Non-Lighting Savings Claimed	7.8%	11.5%
Percentage of Savings Claimed in Dwelling Space (kWh)	57.9%	40.3%
Percentage of Savings Claimed in Common Space (kWh)	42.1%	59.7%

[1] Savings were broken in to dwelling vs common spaces based upon the "zone" variable in the tracking system.

3.2 Gas Tracking and Billing Data Summary and Matching

This section reviews the participant and comparison group tracking and billing data activity, completeness, and characteristics, including match rates. There were the tracking dataset received, there were 160 facilities installing gas measures in 2013 (the treatment group for our analysis) and 214 facilities in 2015 (the comparison group in our analysis). When we further examined these participants, it was apparent that some facilities that participated in 2013 and 2015 also installed measures in other years. It was decided to exclude facilities participating in multiple years from the billing analysis due to their possible bias in the program impact results. For example, if we include a facility participating in both 2013 and 2014 in the participant group, the post period will also include savings of 2014 installed measures which will then upward bias the estimated savings. Similarly, if multi-year participants are included in the comparison group, the pre- analysis period and post-installation of earlier year's measures for the same facility may coincide resulting in downward bias of saving estimates. As a result, there are 128 facilities in the participant group that only installed gas measures in 2013 and 175 facilities in our comparison group that only installed in 2015.

3.2.1 Participant Group

Similar to our approach to the electric analysis, DNV GL matched tracking information of 2013 and 2015 participating natural gas facilities with their respective billing information for the period of 2011 – 2015. The gas billing data is at the premise-level and contained information such as interval begin and end dates, total gas consumption during the period, and rate code.

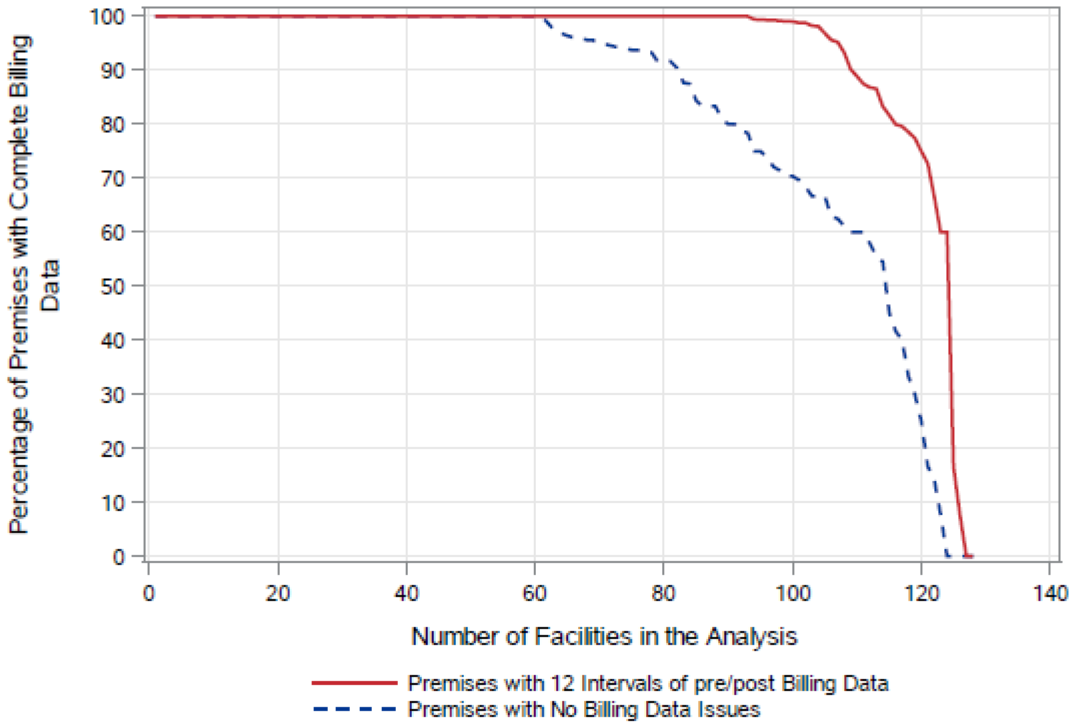
Our first task was to check the status of billing data completeness for each premise within a facility. We did this in the same manner undertaken for the electric analysis. Unlike the electric billing analysis, however, it is not unusual for a premise to have zero gas usage during summer months if gas is only used for heating purposes. We did perform checks on if a premise had at least 12 billing intervals of pre- and post-installation data and if a premise had a usage spike (as defined earlier).

In the gas billing data, DNV GL also created flags to identify premises based on bill usage days and analysis period. We noticed that a significant number of multi-family gas premises have billing data with short bill intervals. We flagged premises if they have more than three billing intervals of less than 20 days in either pre- or post-installation periods. Moreover, we also created flags to find premises that have long analysis period (i.e., premises with less than total usage days of 430 days in either pre or post periods).

Figure 4 contains the number of treated facilities (X axis) with the percentage of their premises (Y Axis) with billing data during the analysis period for 2013 multifamily participants. The solid red line shows the percentage of premises that have at least 12 intervals of billing data in the pre and post periods. The dashed blue line shows the percentage of premises that have at least 12 intervals of billing data in the pre and post periods, no usage spikes, fewer than three billing intervals of less than 20 days in either pre- or post-installation periods and an analysis period of less than 430 days.

Ninety-three facilities have 100% of their premises with the complete billing interval data. Sixty-one facilities have 100% of their premises with complete billing interval data and meet all of the checks described above used to assess the billing data.

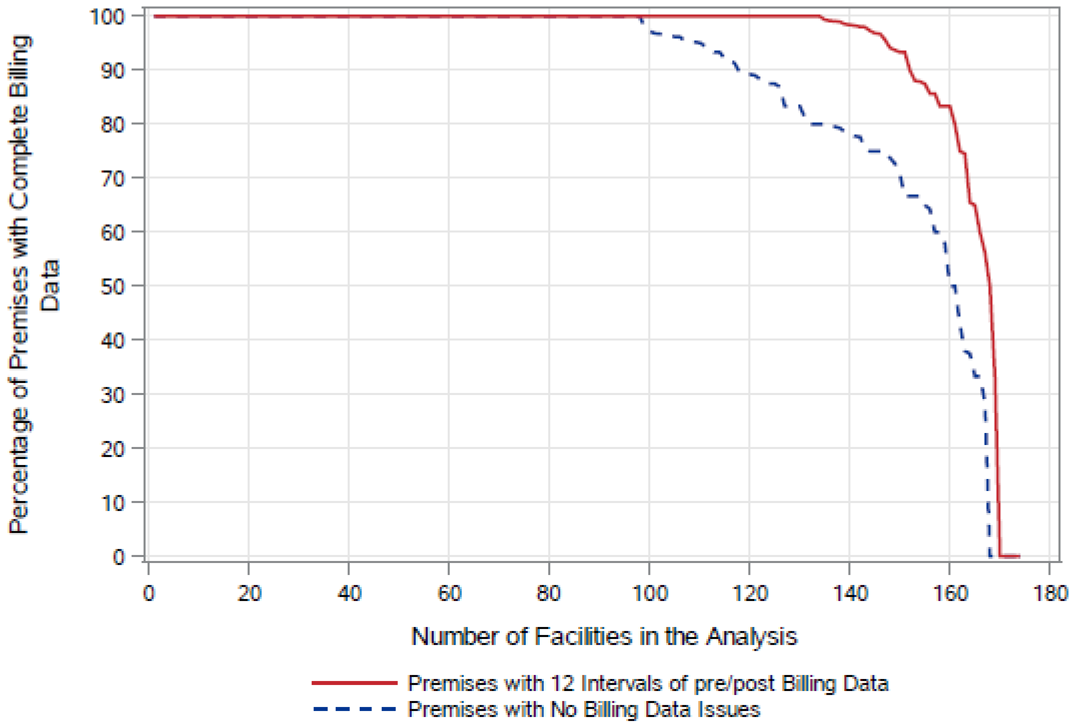
Figure 4: Percentage of Premises within a Facility with Good Billing Data in Treatment Group



3.2.2 Comparison Group

We conducted a similar data assessment of the multifamily gas participants of 2015, which form the comparison group of the impact evaluation. Figure 5 is laid out the same as Figure 4 above. In the comparison group, 134 facilities have 100% of premises with complete billing interval data (red line). Ninety eight facilities have 100% of premises with 12 intervals of billing data in the pre and post periods, no usage spikes, fewer than three billing intervals of less than 20 days in either pre- or post-installation periods and an analysis period of less than 430 days.

Figure 5: Percentage of Premises within a Facility with Good Billing Data in Comparison Group



3.2.3 Final Gas Data Disposition

DNV GL assessed the quality of matched gas billing data at the premise-level and compared the distribution with the total number of premises available in the participant and comparison groups. Table 3 shows the distribution of premises with different gas billing data issues for both participant and comparison group facilities. There are 4,542 premises in the participant group, whereas the comparison group has 3,691.

In our analysis approach, described more fully in the next section, we start with premises of both groups that have at least 12 months of pre- and post- billing interval data including premises with usage spikes, short bill intervals and long analysis periods. Specifically, we start the analysis by excluding 213 premises from the participant group and 146 premises from the comparison group (i.e., all of those with "No" in the "premises with 12 pre/post billing intervals" column). We then perform a staged analysis that excludes premises that have usage spikes, then those with short bill intervals, and finally those with long bill analysis periods. Looking at the results by subsets in this way allows us to check the consistency of the results.

Table 3: Billing Data Status of Premises of Matched Facilities

Premises with 12 pre/post billing intervals	Premises with Usage Spike	Premises with short bill intervals	Premises with long analysis period	MF 2013		MF 2015	
				Premise Count	Percent of Total	Premise Count	Percent of Total
Yes	No	No	No	3,651	80.4%	3,101	84.0%
Yes	No	No	Yes	156	3.4%	114	3.1%
Yes	No	Yes	No	302	6.6%	140	3.8%
Yes	No	Yes	Yes	46	1.0%	16	0.4%
Yes	Yes	No	No	112	2.5%	129	3.5%
Yes	Yes	No	Yes	20	0.4%	28	0.8%
Yes	Yes	Yes	No	34	0.7%	12	0.3%
Yes	Yes	Yes	Yes	8	0.2%	5	0.1%
No	No	No	No	116	2.6%	99	2.7%
No	No	No	Yes	42	0.9%	20	0.5%
No	No	Yes	No	29	0.6%	10	0.3%
No	No	Yes	Yes	9	0.2%	3	0.1%
No	Yes	No	No	12	0.3%	7	0.2%
No	Yes	No	Yes	2	0.0%	2	0.1%
No	Yes	Yes	No	1	0.0%	4	0.1%
No	Yes	Yes	Yes	2	0.0%	1	0.0%
Total				4,542	100%	3,691	100%

3.2.4 Tracking Data Summary

As discussed earlier, DNV GL received tracking information for 2013 and 2015 multi-family gas participants from National Grid. The program tracking data contained information such as installation dates, measure types, and claimed savings.

Table 4 contains the distribution of multifamily facilities installing gas measures only in 2013 and only in 2015 by business sector and facility size according to the tracking data. Sixty six percent of the facilities that participated in 2013 were in the residential sector while 57% of those in 2015 were from the residential sector. As we see in Table 4, the distributions of facilities belonging to different categories are largely comparable across 2013 and 2015.

Table 4: Distribution of Natural Gas Facilities by Business Sector and Facility Size

Business Sector	Facility Size	2013		2015	
		Facility Count	Percent of Total	Facility Count	Percent of Total
Commercial & Industrial	5 to 20 units	11	8.6%	23	13.1%
Commercial & Industrial	Over 20 units	33	25.8%	52	29.7%
Residential	5 to 20 units	36	28.1%	52	29.7%
Residential	Over 20 units	48	37.5%	48	27.4%
Total		128	100.0%	175	100.0%

Table 5 includes the tracking summary statistics for facilities installing measures for both participant and comparison groups. The facilities included in Table 5 only participated in a single year, either 2013 or 2015, and belong to both residential and commercial & industrial business sectors. There are 4,542 premises belonging to 128 facilities that participated in 2013. The total claimed savings for measures installed in 128 facilities is 444,354 therms. Out of the total savings, 66.9% were claimed for measures installed in dwelling spaces with the remaining 33.1% of coming from installations in common spaces. The total claimed savings for the 175 facilities that installed measures only in 2015 is 487,928 therms. The distribution of savings claimed for dwelling and common spaces are 49.2% and 50.8%, respectively. The table shows that the savings percentage of measures installed in common spaces in 2015 is 17.7% more than that of 2013.

Table 5: Tracking Data Summary

Description	MF 2013	MF 2015
Number of Facilities	128	175
Number of Premises	4,542	3,691
Total Annual Claimed Savings (Therms)	444,354	487,928
Percentage of Savings Claimed in Dwelling Space (Therms)	66.9%	49.2%
Percentage of Savings Claimed in Common Space (Therms)	33.1%	50.8%

Table 6 presents a breakdown of measure level gas savings for the treatment and control groups by business sector. The efficiency measures installed in multifamily units can be grouped into five major groups – air sealing, custom, insulation, showerhead and thermostat. For single-year facilities of the participant group (2013 installing facilities) belonging to C&I business sector, insulation measures claimed 37.1% of the savings. The claimed savings for thermostat and air sealing measures for C&I facilities of 2013 are 25.6% and 22.7%, respectively. However, for residential facilities of 2013 installers, the distribution of savings across measure groups is slightly different. The total savings belonging to thermostat and air sealing measures are almost the same at around 35% each. Insulation savings for residential facilities of 2013 is only 23% of total claimed savings.

The distribution of savings for both C&I and residential facilities of the comparison group facilities is slightly different from the same sector of the participant group, especially for showerhead and thermostat measures. The share of claimed savings for showerhead increased significantly from 2013 to 2015, whereas thermostat savings decreased from that of 2013. The difference is savings distribution between participant and comparison group facilities may have to do with the program design.

Table 6: Treatment and Comparison Group Gas Measure Savings by C&I vs Residential

Measure Groups	MF 2013				MF 2015			
	C&I Facilities		Residential Facilities		C&I Facilities		Residential Facilities	
	Therms	%	Therms	%	Therms	%	Therms	%
Air Sealing	54,620	22.7%	73,243	35.9%	51,822	16.8%	76,169	42.1%
Custom	0	0.0%	0	0.0%	17,870	5.8%	0	0.0%
Insulation	89,217	37.1%	46,954	23.0%	97,736	31.7%	50,440	27.9%
Showerhead	34,756	14.5%	12,718	6.2%	83,670	27.1%	29,684	16.4%
Thermostat	61,578	25.6%	71,267	34.9%	57,147	18.5%	24,585	13.6%
Total	240,171	100.0%	204,182	100.0%	308,245	100.0%	180,878	100.0%

4 METHODOLOGY

The electric and natural gas billing analysis conducted in this study was comprised of a two-stage, facility-level, difference-of-differences modelling approach for energy consumption using a panel dataset combining consumption and weather. 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[2]. The method employed is described more fully below.

4.1 Analysis Method

DNV GL used a two-stage billing analysis approach to estimate the impact of electric and natural gas energy efficiency measures in the 2013 multi-family participants. The first stage involved site-level modeling and the second stage applied a difference-in-differences method to measure program savings.

Site-level Modeling: DNV GL conducted site-level modeling[3] to estimate: (a) individual outdoor temperatures that trigger cooling and heating for each program participant, and (b) weather-adjusted consumption that reflects a typical weather year for each site.

The site-level modeling covers a range of cooling and heating degree day bases to estimate normalized annual consumption for pre- and post- installation periods of each household in the participant and comparison group. This modeling approach searches for the optimal reference temperature that yields the best model fit, separately for each premise during the pre- and post-periods. Using the coefficient estimates of the best model selected for each site, we calculated normalized annual consumption using the parameter estimates (see Equation 2 in Appendix A).

Difference-in-Differences: The second stage followed a difference-in-differences method that compares the change in the average normalized consumption of the participant group during pre- and post-program period with the change in usage during the same period for the comparison group (see Equation 3 in Appendix A).

The difference-in-differences approach is a simple, robust approach to measuring program-related savings. The participant group pre-post difference captures all changes between the two periods including those related to the energy efficiency program. The comparison group captures all changes between the two periods with the exception of those related to installed energy efficiency measures. Removing the non-program differences, as represented by the comparison group difference, from the treatment difference produces an estimate of the various installed efficiency measures' isolated effect on the consumption.

Table 7 further summarizes the methodology behind estimating program impact with the difference-in-differences approach. For participants that installed a measure in 2013, the difference in consumption between the pre- and post-periods provides an estimate that combines program-related effect and exogenous (non-program-related, natural trend) change. Their comparison group is made up of facilities and premises that were program participants from 2015. The consumption difference from the two year-long pre-program period for the comparison group captures only exogenous changes. Removing the

[2] 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

[3] The site-level modeling approach used here is similar to the approach originally developed for the Princeton Scorekeeping Method (PRISM™) software.

comparison group's pre-post difference (exogenous, natural trend only) from the 2013 participants' group pre-post difference (program + exogenous, natural trend) provides an estimate of change in consumption due to the Multifamily Program.

Table 7: Pre- and Post- Differences of Participants and Comparison Groups

Group	Pre	Post	Pre-post difference within group	Pre-post difference between groups
2013 Participants	Non-program trend	Non-program trend + Program effect	Program impact + Non-program impact	Program impact
Subsequent participants 2015 Comparison	Non-program trend	Non-program trend	Non-program impact	

4.2 Construction of Comparison Group

The difference-in-differences approach uses a comparison group with similar energy consumption characteristics to control for the non-program, exogenous change in energy consumption through the evaluation period. In a randomized control trial experimental setting, where customers are randomly assigned to the control and treatment groups, this allows for an unbiased measure of program savings, by design. The multifamily energy efficiency program is an opt-in rebate program where it is not feasible to obtain randomly selected customers in control and treatment groups. In this case, it is necessary to construct a comparison group. Following the guidance of DOE's Universal Methods Project, our electric and gas analysis uses participants of 2015 as the comparison group.[4]

The facilities participating in 2015 are randomly matched with facilities installing measures in 2013. Moreover, for gas billing analysis we also made sure that matched facilities belong to same business sector and facility size. The distributions of facilities by business sector and size for the gas facilities are reported in Table 4.

Once the facilities from 2015 are matched, DNV GL constructed a two-year pre-installation period that mirrors the pre- and post-installation of the participants being evaluated. The first of the two pre-installation years of the comparison group corresponds to participant's pre-installation period while the second pre-installation year of the comparison group corresponds to the post-installation period of the participants. The year over year change in comparison group's consumption during the two years of pre-program consumption data provide a basis for addressing non-program change in the estimates of savings.

4.3 Interactive Effects

The tracking data shows that 30 facilities from the participant group installed both gas and electric efficiency measures. Unless otherwise accounted for, the gas billing analysis incorporates the impact of lighting interactive effects (IE) for facilities installing efficient light fixtures. The energy-efficient lighting fixtures emit less heat than higher wattage fixtures, which in turn increases gas consumption used to maintain heating load in the winter. In the absence of this adjustment, this would depress the estimate of gas

[4] *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/2013/07/f2/53827_complete.pdf

savings. Providing results both with and without interactive allows us to show a gas savings and realization rate that reflects impacts when those measures are installed with and without a change in efficient lighting.

To account for this, we used the heating fuel IE factor calculated in a recent lighting interactive study conducted by Cadmus group provided by the Program Administrators[5]. The heating fuel IE factor is the ratio of whole-building heating fuel increase to the electric energy savings (kWh) from the lighting retrofit. The results memo reported heating fuel IE factor of 1,783 Btu/kWh for low-rise multifamily buildings and 1,769 Btu/kWh for high-rise multifamily buildings. We used 1,776 Btu/kWh to adjust for interactive, which is the average heating fuel interactive effects of low-rise and high-rise multifamily buildings. This means that a lighting retrofit will have an average of 1,776 Btu increase in consumption per kWh savings in lighting.

In the event that there is not a need for the inclusion of interactive effects in the gas savings estimates, we provide impacts in all of the gas results tables both with and without interactive effects. When interactive is included, we used the total claimed kWh savings for lighting retrofits in facilities also installing gas measures along with the electric realization rate. There is no interactive adjustment on the electric side.

5 Lighting Interactive Effects Study Results Memo, June 15, 2016, Cadmus, Table 4.

5 RESULTS

In this section, we present the electric results followed by the gas results.

5.1 Electric Consumption Analysis Results

This section presents the electric results of 2013 participants in the National Grid Multifamily Program. We first provide a comparison of average electric consumption – both actual and weather-normalized. Then, we discuss program savings estimated from the difference-in-differences approach. The initial set of results was developed at the facility level using per-premise usage. Subsequent runs to test the robustness of these results include a variety of alternative approaches including performing the regressions at the premise level. Results that are not statistically significant are noted where appropriate.

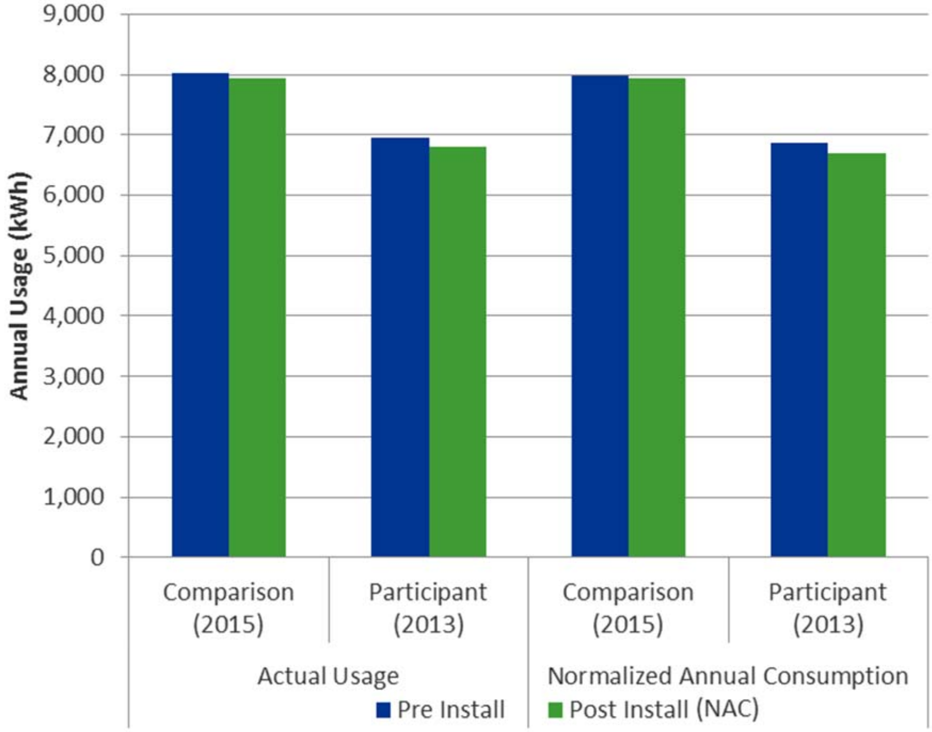
5.1.1 Actual Usage vs Normalized Annual Consumption

Figure 6 shows average annual actual and normalized annual consumption (NAC) of both participants and comparison group during the pre- and post-installation periods. Neither of these groups have low-income facilities in them. This figure provides the components of the difference-in-differences calculation that is used to estimate savings (as described in Table 9). Recall, the participant pre- to post consumption change includes the savings effect of the program as well as any other non-program related changes in consumption that may have occurred between the periods. The pre-post consumption difference for the comparison group captures just the non-program related change.

In both the actual and normalized cases among participants and the comparison group, there is a reduction in consumption from the pre- to post-install periods. As might be expected, this difference is more pronounced in the participant group. Due to the larger reduction of normalized consumption from pre- to post-periods of the participant group than the comparison group, the overall impact of the energy efficiency program resulted in program savings.

We do note that the average consumption of the comparison group is moderately higher than that of the participant group. In this analysis, it is the difference in consumption among the groups, and not their size, that is used to determine impacts. Despite this, we made an effort to more closely align consumption levels with weighting schemes that considered variability across number of premises in each facility and the size of largest premise present within a facility based on the usage. These weighting exercises did not change the average NACs and were not used in the final analysis.

Figure 6: Average Premise-level Electric Actual and Normalized Annual Consumption



5.1.2 Realization Rates

The table below presents the difference in difference results from the facility level regression analysis. To achieve this facility level result, we used per premise level NAC and actual usage and utilized the difference-in-difference regression. This facility level result is weighted by total premise counts by facility to account for premises that did not have sufficient billing data for inclusion in the analysis. The estimated savings per premise is 141 kWh per year. This estimated savings corresponds to a 2.1% usage reduction from the participant group's average pre-period NAC. The realization rate is the ratio of total estimated savings to the total claimed tracking savings. This facility-level difference-in-difference gives a realization rate of 24.4% with a relative precision of ±49.3% (i.e., 141 kWh+49.3% and 141 kWh-49.3%, or a range of 210.5 kWh to 71.5 kWh) at the 90% confidence interval for the electric savings claimed from energy efficiency measures installed in participant facilities. Note that all precisions provide in this report are relative. Later in this section, we also performed an analysis at the premise-level. We believe the facility level results in the table below to be the most appropriate savings estimate of 2013 electric impacts in the Multifamily Program.

Table 8: Estimated Savings and Realization Rates: Difference in Difference at the Facility-level

Description	Per Premise at the Facility-level
Evaluated Annual Savings (kWh/Premise)	141.0
90% Precision on Evaluated Savings	±49.3%
Average Premise-level Pre-NAC (kWh)	6,862
Savings as Percent of Pre-NAC	2.1%
Number of Facilities in Participant Group	268
Number of Facilities in Comparison Group	270
Number of Premises in Participant Group	25,237
Number of Premises in Comparison Group	16,437
Total Realized Annual Savings (kWh)	3,558,796
Total Claimed Annual Savings (kWh)	14,571,847
Realization Rate	24.4%

This section provides results from the regression analysis performed at the premise level. This includes estimates of overall impacts as well as among sub segments of the population. The program level results estimated in this way are effectively the same as those calculated at the facility level.

Table 9 contains the results from the difference-in-difference regression model at the premise level with realization rates for two different scenarios. The first includes all premises that have 12 billing intervals of pre- and post-periods data. The second is based on "good" data that meets our three requirements of having 12 months of pre- and post- period data, no usage spikes and no zero usage. We often perform analyses using different sets of billing data to check the consistency of results and their sensitivity to billing data issues.

The impact analysis that includes all premises (Table 3, Column 1) shows an estimated savings of 143.9 kWh per year for each premise in facilities participating in 2013. At the same time, average normalized annual consumption during the pre-installation period at the premise-level is 6,862 kWh. The estimated savings represents 2.1% of the pre-period NAC usage. To get program level impacts, we multiply per premise savings with the total number of premises in facilities in the participating group. This calculation results in a program savings estimate of 3,631.2 MWh. Using this method and data, we calculate a realization rate of 24.9% with a precision of ±41% at the 90% confidence interval for multi-family facilities participating in 2013.

We then looked at the difference-in-difference results by excluding premises with usage spikes. The sudden spike in the electricity consumption does not represent a regular usage pattern and may bias the savings impact values. However, the difference-in-difference results after excluding premises with usage spikes only produced a marginally lower difference in savings with a realization rate of 23.9%, only slightly less than the results of the full sample. Next, we excluded premises with zero usage, thus removing homes that have been completely shut down in any bill period. The savings impact after also excluding zero usage homes provides a realization rate of 20.2%. This value and its precision are shown in the second column of Table 9.

Table 9: Estimated Savings and Realization Rates: Difference in Difference at Premise-level

Description	Premises with 12 billing intervals of Pre/Post periods	Premises with 12 billing interval of Pre/Post, no usage spikes, and no zero usage
Evaluated Annual Savings (kWh/Premise)	143.9	116.5
90% Precision on Evaluated Savings	±41%	±42.6%
Average Premise-level Pre-NAC (kWh)	6,862	6,758
Savings as Percent of Pre-NAC	2.1%	1.7%
Number of Premises in Participant Group	25,237	24,597
Number of Premises in Comparison Group	16,437	15,988
Total Realized Annual Savings (kWh)	3,631,199	2,940,456
Tracking Annual Savings (kWh)	14,571,847	14,571,847
Realization Rates	24.9%	20.2%

To further examine the electric results, DNV GL explored the analysis across subsets within the analysis population. We compared the difference-in-difference results across three defined groups based on number of premises within each multi-family facility. Since the number of premises of a facility varies considerably, the goal was to create similar participant and comparison groups. We divided the population sample into three different groups – including facilities with low premise counts (<25 percentile of the sample as determined by the combined treatment and control populations), facilities with normal premise counts (25 percentile- 75 percentile of the sample), and facilities with high premise counts (greater than 75 percentile of the sample). The difference-in-difference results from all three groups were similar and consistent with the results of the full sample.

We also examined the results by separating residential premises by read type. Among different read types available in the monthly usage dataset, the data contain 'Final' bill read types, which reflect the final reading of one account before a new billing account is opened in the same premise. We examined results by read type to identify premises that have occupancy issues in pre- and/or post-installation periods for both comparison and participant groups. In this analysis, the pre-post NAC differences for both the participant and comparison group behaved the way one would expect with regards to periods of occupied vs unoccupied (e.g., savings increased when vacancy was observed in the post period and savings decreased when vacancy was observed in the pre period). However, there were no statistically significant results observed among any of the subsets examined. Additionally, when we isolated premises with no vacancy issues the resulting savings work showed no evidence that vacancy is affecting the overall results.

DNV GL also examined results by commercial versus residential bill rates. These results are provided in Table 10 below. Due to tracking data being at the facility level and billing data at the account or premise level we are unable to provide realization rates in this and some subsequent tables. However, it is clear from this analysis that participants with commercial bill rates are experiencing a much higher level of savings (3,704 kWh, or 7.4% of consumption) than residential (14.2 kWh, or 0.2% of consumption), although we note the precision around the residential result is very poor at ±236.4% and is not statistically significant.

Table 10: Estimated Savings and Realization Rates: Separating Premises by Bill Rate Types

Description	Premises with Commercial Bill Rates	Premises with Residential Bill Rates
Evaluated Annual Savings (kWh/Premise)	3,704.4	14.2†
90% Precision on Evaluated Savings	±38.4%	±236.4%
Average Premise-level Pre-NAC (kWh)	50,007.2	6,862.1
Savings as Percent of Pre-NAC	7.4%	0.2%
Number of Premises in Participant Group	921	24,316
Number of Premises in Comparison Group	532	15,905

† Not statistically significant at 10%.

Finally, we examined results by apartment versus condominium ownership type. These results were largely consistent with the results obtained using the full sample. The saving estimates were stable and did not significantly differ across these sub segments.

Table 11: Estimated Savings and Realization Rates: Separating Facilities by Ownership Types

Description	Apartments	Condominiums
Evaluated Annual Savings (kWh/Premise)	190.2	140.7
90% Precision on Evaluated Savings	±55.7%	±40.9%
Average Premise-level Pre-NAC (kWh)	6,467.4	7,496.5
Savings as Percent of Pre-NAC	2.94%	1.88%
Number of Premises in Participant Group	15,546	9,675
Number of Premises in Comparison Group	6,480	9,800

DNV GL also analyzed program impacts by removing facilities that installed only instant saving measures (ISMs) and/or in-unit lighting. The goal of this exercise was to see how estimated savings differ when analysis was run using all facilities versus excluding facilities with ISMs. Table 12 represents the distribution of facilities from the participant group by electric measures installed in 2013. The table shows distribution of five measure groups. The lighting measures installed in the multifamily facilities are divided into exterior, common area, and in-unit based on the location of the fixtures installed. And, two additional measure groups are ISMs and "other". The ISMs group includes showerhead, aerator, smart strips, and thermostat. The "other" measure category includes insulation, refrigerator, air sealing, HVAC, and domestic hot water.

The table shows that there are 45 facilities (out of 268) in the comparison group that installed a combination of in-unit lighting and ISMs. These facilities contained 7.7% of the total claimed savings reported for the comparison group. DNV GL ran a separate difference-in-difference model by excluding these 45 facilities to estimating savings of energy efficiency programs. The results are reported in Table 13.

Table 12: Distribution of Participant and Claimed Electric Savings by Measures Installed

Participation Year	Measure Groups					Facility Count	Claimed savings (KWh)	Share of Total Facility Count	Share of Claimed Savings
	Lighting Exterior	Lighting Common Area	Lighting Dwelling Unit	Instant Saving Measures	Other				
2013	0	0	1	0	0	30	481,104	11.2%	3.3%
2013	0	0	1	1	0	15	634,357	5.6%	4.4%
2013	0	0	0	0	1	6	52,980	2.2%	0.4%
2013	0	0	1	1	1	11	409,051	4.1%	2.8%
2013	0	1	0	0	0	2	3,027	0.7%	0.0%
2013	0	1	1	0	0	6	117,333	2.2%	0.8%
2013	0	1	1	1	0	7	172,798	2.6%	1.2%
2013	1	0	0	0	0	50	1,475,272	18.7%	10.1%
2013	1	0	0	0	1	2	38,957	0.7%	0.3%
2013	1	0	0	1	0	4	223,488	1.5%	1.5%
2013	1	0	1	0	0	11	717,672	4.1%	4.9%
2013	1	0	1	0	1	1	54,880	0.4%	0.4%
2013	1	0	1	1	0	30	1,516,523	11.2%	10.4%
2013	1	0	1	1	1	7	374,953	2.6%	2.6%
2013	1	1	0	0	0	4	209,839	1.5%	1.4%
2013	1	1	0	0	1	1	51,828	0.4%	0.4%
2013	1	1	0	1	0	1	42,587	0.4%	0.3%
2013	1	1	0	1	1	1	31,090	0.4%	0.2%
2013	1	1	1	0	0	34	3,962,733	12.7%	27.2%
2013	1	1	1	0	1	1	75,546	0.4%	0.5%
2013	1	1	1	1	0	32	3,328,743	11.9%	22.8%
2013	1	1	1	1	1	12	597,086	4.5%	4.1%
					Total	268	14,571,847	100.0%	100.0%

The analysis shows the estimated per-premise level savings, after excluding facilities installing only in-unit lighting and ISMs measures, is 149.6 kWh per year. This provides a realization rate of 25.1% with a precision of ±49%. The per-premises estimated savings and realization rates reported in Table 13 is slightly higher than the ones estimated using all facilities, irrespective of measures installed (the results are reported in Table 8). The pre-premise estimated savings increase from 141.0 kWh/year to 149.6 kWh/year. However, this increase in pre-premise savings translated into slight increase in realization rates from 24.4% to 25.1%.

Table 13: Electric Savings and Realization Rates Excluding Facilities with only ISMs

Description	Excluding Facilities with only in-unit Lighting & ISMs
Evaluated Annual Savings (kWh/Premise)	149.6
90% Precision on Evaluated Savings	±49.2%
Average Premise-level Pre-NAC (kWh)	6,847.8
Savings as Percent of Pre-NAC	2.18%
Number of Facilities in Participant Group	223
Number of Facilities in Comparison Group	265
Number of Premises in Participant Group	22,513
Number of Premises in Comparison Group	16,348
Total Realized Annual Savings (kWh)	3,381,318
Total Claimed Annual Savings (kWh)	13,456,386
Realization Rates	25.1%

5.1.3 Exploring Possible Causes of the Electric Realization Rate

The low realization rates observed in this study may be due to various things. They might be due to any one or combination of issues in short term persistence, lower than anticipated installation rates, general quality of measure installation, the presence of free ridership, or the overestimation of measure savings in the tracking system estimates. Based on our knowledge of this program and its operations, however, we believe the most reasonable first place to explore possible drivers of the realization rates are in the assumptions that drive the measure savings in the tracking system (the ex-ante estimates).

Given the dependence of program savings on lighting measures (>92% of program savings), we decided to focus on those savings estimates and assumptions in the tracking system. This exploration is most useful when done at the zone level as provided in the tracking data (common exterior, common interior and dwelling unit). This approach allows us to better assess what appears to be reasonable vs unreasonable calculation inputs (e.g., watts and hours of use).

Table 14 shows the number of bulbs, pre and post system types and pre and post watt averages weighted by measure quantity installed by zone. The vast majority of bulbs installed are in dwelling units (95%). The Multifamily Program is a direct installation program and replaces incandescent bulbs and the occasional high pressure sodium lamp. Examining the bulbs installed in dwelling units, the average pre watt appear reasonable at 60 watts when a CFL is installed and 65 when an LED is installed. The average post watts similarly appear reasonable for LED and CFLs replacing 60 watt incandescent bulbs in dwelling units at 18 watts for installed CFLs and 11 for LEDs.

Table 14: Pre and Post Lighting Systems and Watts by Meter Type

Zone Type	n	Existing System	Installed System Type	Watts (per Bulb)	
				Pre	Post
Common (Exterior)	41	Incandescent Lamps	Compact Fluorescent Lamps	40.0	14.0
	1,057	Incandescent Lamps	LED Bulb	74.2	13.7
	2,930	Sodium - High Pressure	LED Bulb	142.5	37.2
Common (Interior)	170	Incandescent Lamps	Compact Fluorescent Lamps	60.5	17.2
	1,277	Incandescent Lamps	LED Bulb	55.5	9.6
	48	Sodium - High Pressure	LED Bulb	112.9	31.6
Dwelling Unit	43,708	Incandescent Lamps	Compact Fluorescent Lamps	60.4	17.6
	56,154	Incandescent Lamps	LED Bulb	65.1	11.5
	5	Sodium - High Pressure	LED Bulb	130.0	20.0

Table 15 presents the weighted average daily hours of use by system type for interior common areas, dwelling units and exterior lighting by zone. In the rightmost column, we provide the average daily hours of use as calculated from loggers installed in multifamily facilities as part of the large Hours of Use Study performed across the Northeast in 2014[6] (HOU Study) and the recently completed Massachusetts Low☐ Income Multifamily Initiative Impact Evaluation[7]. Unfortunately, neither study provides a point of comparison for common interior lighting hours for comparison.

In considering common exterior hours, the overall average estimate of exterior hours from the tracking system ranges from 6.9 for CFL installations to roughly 12 hours a day for all LED installations. These compare to an overall value from the regional HOU study of 7.5 for multifamily (based on 5 sites). This small sample in the HOU Study presents a great deal of uncertainty around those results. The recently completed Low-Income Multifamily Initiative Impact Evaluation[8] also examined the operating hours of exterior fixtures and concluded that 12 hours per day is a reasonable estimate. Given the HOU study and the Multifamily Low Income study results, the range of hours assumed for exterior lighting in the tracking system appear reasonable.

The tracking hours of use in dwelling units vary between CFLs (2.2 hours per day) and LEDs (3.1 hours per day). One would expect these numbers to be more similar, assuming they are each installed comprehensively throughout each treated unit. The overall average daily hours of use for multifamily from

---

[6] Northeast Residential Lighting Hours-of-Use Study, Final, 5/5/2014, Appendix A, Nexus Market Research
[7] http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Multifamily-Impact-Evaluation-1.pdf
[8] http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Multifamily-Impact-Evaluation-1.pdf

the HOU Study is 2.7[9]. This suggests that CFL tracked hours of use might be underestimated and LED's might be overestimated.

Table 15: Average Daily Hours of Use by Lighting System and Meter Type

Zone Type	n	Existing System	Installed System Type	Average Daily Usage (Hrs)	Comparison Source
Common (Exterior)	41	Incandescent Lamps	Compact Fluorescent Lamps	6.9	7.5* 12.0Ŧ
	1,057	Incandescent Lamps	LED Bulb	11.6	
	2,930	Sodium - High Pressure	LED Bulb	12.0	
Common (Interior)	170	Incandescent Lamps	Compact Fluorescent Lamps	5.7	N/A
	1,277	Incandescent Lamps	LED Bulb	12.1	
	48	Sodium - High Pressure	LED Bulb	24.0	
Dwelling Unit	43,708	Incandescent Lamps	Compact Fluorescent Lamps	2.2	2.7*
	56,154	Incandescent Lamps	LED Bulb	3.1	
	5	Sodium - High Pressure	LED Bulb	10.0	

* Regional Hours of Use Study Ŧ Massachusetts Low☐Income Multifamily Initiative Impact Evaluation

To further examine the tracking hours of use, we categorized bulbs to the extent possible based upon a location text field in the database. This field was not always populated with actual room locations as it often carried the fixture type (e.g., chandelier, table lamp, etc.) the bulb was installed in. We only looked at the bulbs installed in dwelling units, given their share of all bulbs installed. A summary of this review is provided in Table 16 below. Similar to the previous table, in the rightmost column is the average daily hours of use for multifamily households from the regional HOU study. Examining the hours of use in this way does not raise any substantial concerns about operating hour assumptions. In fact, for all but exterior, the classifiable locations in the table below has tracking system average hours that fall within the error band of the HOU Study at the 90% confidence interval.

[9] Northeast Residential Lighting Hours-of-Use Study, Final, 5/5/2014, Appendix A Table A-5, Nexus Market Research

Table 16: Average Daily Hours of Use by Dwelling Unit Location

Dwelling Location	Proposed Lighting Types Daily Usage Hours						HOU Study
	CFL		LED		Both		
	N	Hrs	N	Hrs	N	Hrs	
Bathroom	7,840	2.2	5,278	2.1	13,118	2.2	2.0
Bathroom/Halls		-	782	2.0	782	2.0	1.5Ŧ
Bedroom	1,756	2.0	564	2.9	2,320	2.0	2.3
Bedroom/Halls		-	119	3.0	119	3.0	1.5Ŧ
Closet	4,250	2.0	54	8.0	4,304	2.0	1.5Ŧ
Dining Room		-	3,061	2.8	3,061	2.8	2.7
Exterior	57	4.4	1,492	2.2	1,549	2.2	7.5
Halls	197	3.0	2,106	2.8	2,303	2.8	1.5Ŧ
Kitchen		-	3,608	4.1	3,608	4.1	3.8
Kitchen/Dining		-	2,599	3.5	2,599	3.5	-
Unclassifiable	29,608	2.4	36,477	3.2	66,085	2.9	2.7*

*Overall HOU estimate for multifamily households Ŧ HOU estimate for "Other" categories, including unfinished basements, foyers, offices, hallways, closets, utility rooms and garages.

Based on the review of the tracking data as described above, it is difficult to determine a clear driver of the realization rate. One remaining possibility is that the 66,085 unclassifiable installations that have average daily hours of use of 2.9 are, in fact, installed in locations with low operating hours. In a Massachusetts Onsite Lighting Inventory performed in 2013[10], 55% of sockets in the residential market (single family and multifamily) had incandescent bulbs installed. Recall, incandescent bulbs are the primary target for replacement in the Multifamily Program. That same study found incandescent bulbs typically found to be present in dining rooms, foyers, bathrooms, halls, exterior, and bedrooms. Depending on the mix of locations where these units were installed in, their hours may be below the 2.9 average daily hours of use estimated in the tracking system.

5.2 Gas Consumption Analysis Results

This section presents the gas results of 2013 participants in the National Grid Multifamily Program. Like the electric results presented earlier, we first provide a comparison of average electric consumption – both actual and weather-normalized – during pre and post installation periods. Then, we discuss program savings estimated from the difference-in-difference approach. The initial set of results was developed at the facility level using the per-premise usage. Subsequent runs to test the robustness of these results include a variety of alternative approaches including performing the regressions at the premise level, separating facilities by characteristics such as business sector, ownership type, and facility size. Results that are not statistically significant are noted where appropriate.

[10] http://ma-eeac.org/wordpress/wp-content/uploads/Onsite-Lighting-Inventory-Results-Final-Report-6.7.13.pdf

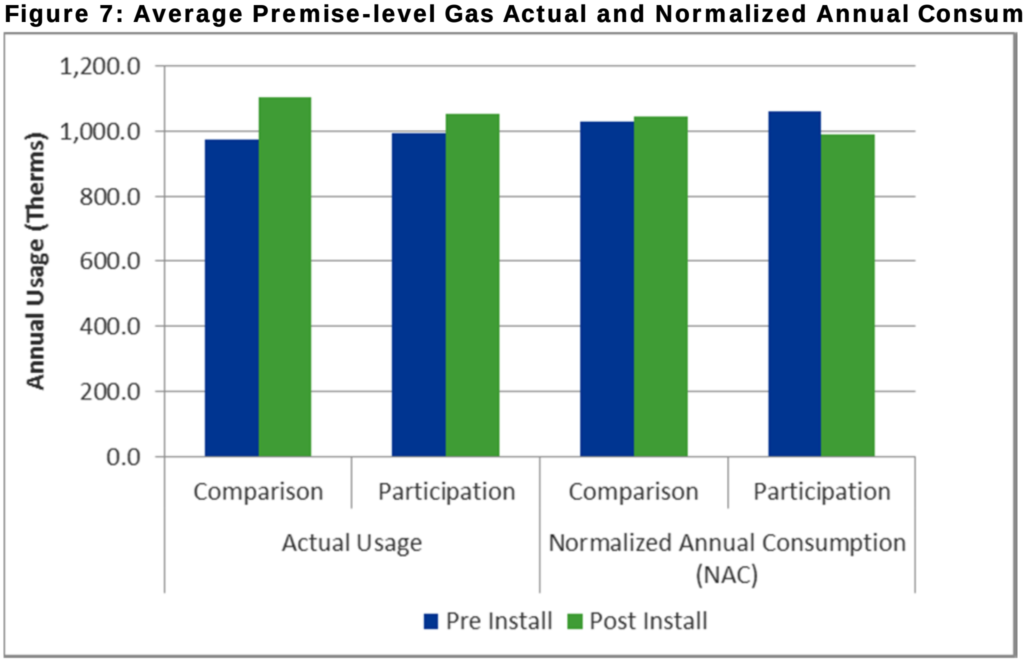
5.2.1 Actual Usage vs Normalized Annual Consumption

Figure 7 shows average annual actual and normalized annual consumption (NAC) of both the participant and comparison group during the pre- and post-installation periods. The normalized annual consumption and actual annual usage values are weighted by the ratio of facilities available in participant and comparison groups in different combinations. DNV GL established this weighting mechanism in order to create similar participant and comparison groups. This was done by considering variability across facilities based on business sector, ownership type, and facility size. We calculated the number of facilities available in each combination using size, ownership, and business sector. Then, we calculated the ratio by dividing the number of participating facilities by facility counts in the comparison group for each category. We then applied this ratio to weight NAC of the comparison group's premises. As a result, we are able to create a comparison group that is more representative of the treatment group with respect to the number of facilities within these strata.

Figure 7 shows that the average actual annualized usage for both participant and the weighted comparison groups increased from pre to post period. The increase in consumption in the post period is most likely due to do with difference in weather patterns. The post period, for most of the premises, includes 2014 winter, whereas pre period includes 2013 winter. In Massachusetts, the average monthly temperature of winter months in 2014 was lower than winter months of 2013.

However, the direction of average NAC from pre to post period is different for the comparison and participant groups. The figure shows that the average post-NAC of the comparison group is slightly greater than the average pre-NAC. Whereas the average post-NAC of participant group premises is lower than the average pre-NAC. The opposite movements of pre to post NACs of participant and comparison group suggest two things. The first is that the PRISM regression models used for weather normalization were able to control for weather dependent gas consumption. The second is that the Multifamily energy efficiency program is resulting in gas savings.

Figure 7: Average Premise-level Gas Actual and Normalized Annual Consumption



5.2.2 Realization Rates

Table 17 contains the results of the facility level difference-in-difference regression analysis using the per-premise NAC values. Among other things, this table includes premise and facility counts, normalized consumption, annual savings, and realization rates. To get the pre premise values, we rolled the NAC values of all premises with 12 intervals of billing data in both the pre and post periods at the facility-level and divided by the total number of premises in each facility. This difference-in-difference model is also weighted by total premises available in the raw billing dataset. As noted earlier, there are 4,542 premises in the raw billing data. Among these, 4,329 premises have 12 billing intervals of data in both pre and post periods and are used in the regression analysis. Table shows that the estimated savings from the billing analysis is 84.4 therms per premise in facilities installing measures in 2013. The precision of evaluated savings, at the 90% confidence interval, is ±64.1%. Our analysis provides an average pre-period NAC for participating premise of 1,060.4 therms. This results in an estimated savings result that represents 7.95% of the average pre-NAC.

In the table below we provide two estimates of overall gas savings; one with interactive and one without. Recall, interactive is an adjustment made to compensate for the increase in gas consumption due to installation of efficient lighting measures. This adjustment was calculated based on 30 participating facilities installing gas measures in 2013 that also reported to have 1,144,998 kWh of claimed lighting savings. Using the electric billing analysis realization rate of 24.4%, we estimate realized lighting savings of 279,380 kWh. The final adjustment due to lighting interactive effects uses the Btu/kWh values from the lighting interactive memo[11] to estimate the therms adjustment. This calculation is 279,380 kWh * 1,776 Btu/kWh = 496.2 MMBtu, which equals to a lighting interactive effect of 4,963 Therms.

We calculated total estimated savings without interactive by multiplying the per-premise estimated savings by the total number of premises available from the raw billing data. The realization rates is then calculated by dividing the sum of total estimated savings (with and without the lighting interactive adjustment) by the total savings reported in the tracking data. Our analysis estimated a realization rate of 86.2% without interactive and 87.3% with interactive. The precision is the same for both estimates (±64.1%) as they are based upon normalized energy consumptions as calculated from actual billing and weather information. We believe the facility level results in the table below to be the most appropriate savings estimate of 2013 natural gas impacts in the Multifamily Program.

[11] Lighting Interactive Effects Study Results Memo, June 15, 2016, Cadmus, Table 4.

Table 17: Estimated Savings and Realization Rates: Difference in Difference at the Facility-level

Description	Per Premise at the Facility-level
Evaluated Annual Savings (Therms/Premise)	84.4
90% Precision on Evaluated Savings	±64.1%
Average Premise-level Pre-NAC (Therms)	1,060.4
Savings as Percent of Pre-NAC	7.95%
Number of Facilities in Participant Group	126
Number of Facilities in Comparison Group	169
Number of Premises in Participant Group	4,329
Number of Premises in Comparison Group	3,545
Total Realized Annual Savings without Interactive Adjustment (Therms)	383,129
Total Claimed Annual Savings (Therms)	444,354
Realization Rate without Interactive Adjustment	86.2%
Lighting Interactive Adjusted Savings (Therms)	4,963
Total Realized Annual Savings with Interactive Adjustment (Therms)	388,092
Realization Rate with Interactive Adjustment	87.3%

Akin to the electric results presented earlier, we also performed the difference-in-difference analysis on various specifications of the data. The goal of this was to check the consistency of results when premises with different billing issues are excluded from the analysis. All the following models use premise-level NAC values in the respective regression models.

Table 18 contains the results from the difference-in-difference regression model at the premise level with realization rates for four different scenarios. We started by including all premises that have 12 billing intervals of pre- and post-periods data, which is presented in the first column. This column of results differs from those in Table 17 because the results in Table 18 are weighted by the number of premises available in the raw billing dataset. The second column of results excludes premises with usage spikes. In the third column, we removed premises with more than three usage intervals of less than 20 days in either the pre or post period. In the final column of Table 18, we further excluded premises that have total usage days greater than 430 in their pre or post period. The number of premises of each column shows the size of the sample included in each model.

The impact analysis that includes all premises (Table 18, Column 1) shows an estimated savings of 86.7 therms per year for each premise in facilities participating in 2013. This provides a realization rate of 88.6%

without interactive and 89.7% with, each of them with a precision of ±53.4% at the 90% confidence interval. At the same time, average premise-level normalized annual consumption during the pre-installation period at the premise-level is 1,060.4 therms. The estimated program savings from this analysis is 8.18% of pre-period NAC usage.

The subsequent columns on Table 18 contain the results of scenarios applying different exclusion criteria as described earlier. The estimated savings at the premise-level vary from 82.3 – 93.4 therms per year among the three different scenarios considered. The difference-in-difference results after excluding premises with usage spikes produced a marginally lower difference in savings with interactive with a realization rate of 85.2%, only slightly less than the results of the full sample. Next, we excluded premises with short bill intervals, thus removing homes that have irregular reads. The savings impact after excluding short interval bill periods provides a realization rate with interactive of 93.9%. When we further excluded premises with analysis period of longer than 430 days (14 months), the realization rates increased slightly to 97.7%. In various scenarios considered, DNV GL found that the estimated savings vary slightly and the results are consistent across different exclusion criteria considered.

Table 18: Estimated Savings and Realization Rates: Difference in Difference at the Premise-level

Description	All premises	All, excluding spikes	All, excluding spikes & short intervals	All, excluding spikes & short intervals & long period
Evaluated Annual Savings (Therms/Premise)	86.7	82.3	89.7	93.4
90% Precision on Evaluated Savings	±53.4%	±58.2%	±57.0%	±56.8%
Average Premise-level Pre-NAC (Therms)	1,060.4	1,087.0	1,143.6	1,087.8
Savings as Percent of Pre-NAC	8.18%	7.57%	7.84%	8.59%
Number of Premises in Participant Group	4,329	4,155	3,807	3,651
Number of Premises in Comparison Group	3,545	3,371	3,215	3,101
Total Realized Annual Savings without Interactive Adjustment (Therms)	393,832	373,653	412,406	429,198
Total Claimed Annual Savings (Therms)	444,354	444,354	444,354	444,354
Realization Rate without Interactive Adjustment	88.6%	84.1%	92.8%	96.6%
Lighting Interactive Adjusted Savings (Therms)	4,963	4,963	4,963	4,963
Total Realized Annual Savings with Interactive Adjustment (Therms)	398,795	378,616	417,369	434,161
Realization Rate with Interactive Adjustment	89.7%	85.2%	93.9%	97.7%

We also performed the impact analysis on sub segments of the population by dividing participants into different groups based on their business, ownership and types. On each of these, we ran separate difference-in-difference models on premises of the facilities that have at least 12 billing intervals in the pre and post period.

Table 19 includes the results of difference-in-difference regression models after separating multifamily facilities by business sector. The business sector field was available to DNV GL through tracking data and separates facilities into commercial and residential sectors. Program vendors record master metered gas facilities as being “commercial” in the tracking system “business sector” field. The results show that the program experiences very different savings levels for facilities grouped into commercial versus residential sectors. The average premise-level savings in the commercial sector is 1,705 therms per year, or 12.4% of its average pre-period NAC. This results in a 127.1% realization rate with the precision of ±53.1%. There was no interactive in the commercial facilities as none had both lighting and gas measures installed. The analysis showed that the estimated savings of premises in the residential sector is only 17.6 therms per year, or 1.7% of its average pre-NAC. The realization rate for residential sector without interactive is 37.5% and with interactive is 40.0%.

Table 19: Estimated Savings and Realization Rates: Separating Facilities by Business Sector

Description	Commercial Facilities	Residential Facilities
Evaluated Annual Savings (Therms/Premise)	1,705.0	17.6
90% Precision on Evaluated Savings	±53.1%	±54.1%
Average Premise-level Pre-NAC (Therms)	13,743.0	1,060.4
Savings as Percent of Pre-NAC	12.41%	1.66%
Number of Premises in Participant Group	164	4,165
Number of Premises in Comparison Group	229	3,316
Total Realized Annual Savings without Interactive Adjustment (Therms)	305,194.7	76,637.9
Total Claimed Annual Savings (Therms)	240,170.9	204,182.6
Realization Rate without Interactive Adjustment	127.1%	37.5%
Lighting Interactive Adjusted Savings (Therms)	0.0	4,963.0
Total Realized Annual Savings with Interactive Adjustment (Therms)	240,170.9	209,146
Realization Rate with Interactive Adjustment	127.1%	40.0%

We also estimated program savings by examining multifamily facilities by ownership types. The results for facilities belonging to apartments and condominiums are in Table 20. The average savings for premises of multifamily apartment is 146.9 therms per year with realization rate of 108.8% without interactive and 109.7% including the interactive effects. Whereas, the average estimated savings for premises belonging to condominiums is 33.7 therms per year. This results into the realization rate of 68.5% without interactive and 70.4% with.

Table 20: Estimated Savings and Realization Rates: Separating Facilities by Ownership Type

Description	Apartments	Condominiums
Evaluated Annual Savings (Therms/Premise)	146.9	33.7
90% Precision on Evaluated Savings	±67.8%	±62.8%
Average Premise-level Pre-NAC (Therms)	1,162.0	935.9
Savings as Percent of Pre-NAC	12.64%	3.60%
Number of Premises in Participant Group	2,384	1,945
Number of Premises in Comparison Group	1,309	2,186
Total Realized Annual Savings without Interactive Adjustment (Therms)	378,330.5	66,267.4
Total Claimed Annual Savings (Therms)	347,586.5	96,767.0
Realization Rate without Interactive Adjustment	108.8%	68.5%
Lighting Interactive Adjusted Savings (Therms)	3,103.5	1,859.5
Total Realized Annual Savings with Interactive Adjustment (Therms)	381,434.0	68,126.9
Realization Rate with Interactive Adjustment	109.7%	70.4%

We also looked at the program impacts by separating facilities by size. The tracking data included a variable (facility type) allowing us to classify facilities into two groups based on the size. Table 21 contains the difference-in-difference results separately for facilities that have 5 – 20 units and facilities with greater than 20 units. Please note that the first group including premises of facilities that have 5 – 20 units is a much smaller sample than that of premises from facilities with greater than 20 units. The results show a sizeable difference in realization rates between the groups. The average premise-level savings for small size facilities is 39.7 therms per year without interactive, with a realization rate of 54.5%. Whereas, the estimated savings for large facilities without interactive is 90.9 therms which results in a realization rate of 90.7%. Including interactive the realization rates increase to 57.2% for small size facilities and 91.7% for large.

Table 21: Estimated Savings and Realization Rates: Separating Facilities by Facility Size

Description	Facility Size: 5 - 20 Units	Facility Size: >20 Units
Evaluated Annual Savings (Therms/Premise)	39.7	90.9
90% Precision on Evaluated Savings	±96.1%	±55.8%
Average Premise-level Pre-NAC (Therms)	790.1	1,084.1
Savings as Percent of Pre-NAC	5.03%	8.39%
Number of Premises in Participant Group	349	3,980
Number of Premises in Comparison Group	354	3,191
Total Realized Annual Savings without Interactive Adjustment (Therms)	15,607.9	377,171.5
Total Claimed Annual Savings (Therms)	28,634.4	415,719.1
Realization Rate without Interactive Adjustment	54.5%	90.7%
Lighting Interactive Adjusted Savings (Therms)	772.2	4,190.7
Total Realized Annual Savings with Interactive Adjustment (Therms)	16,380.1	381,362.2
Realization Rate with Interactive Adjustment	57.2%	91.7%

Like the electric analysis presented earlier, we also looked at program impacts by removing facilities that installed only instant saving measures (ISMs). Table 22 contains the facility count and claimed savings distribution by gas measures installed in participant facilities in 2013. The three different ISMs installed in gas facilities are thermostat, showerhead, and measures included in the other category. Table 22 shows that there were 51 multifamily facilities (39.8%) that installed only instant measures in the participant group. The share of total claimed savings for facilities installing only ISMs was only 10.5%. DNV GL re-ran the difference-in-difference analysis by removing facilities installing only ISMs from both participant and comparison groups.

Table 22: Distribution of Participant and Claimed Natural Gas Savings by Measures Installed

Participation Year	Measure Groups					Facility Count	Claimed savings (Therms)	Share of Total Facility Count	Share of Claimed Savings
	Air Sealing	Insulation	Thermostat	Showerhead	Other				
2013	0	0	0	1	0	19	7,473.6	14.8%	1.7%
2013	0	0	1	0	0	7	4,972.5	5.5%	1.1%
2013	0	0	1	1	0	25	34,034.7	19.5%	7.7%
2013	0	1	0	0	0	3	2,258.0	2.3%	0.5%
2013	0	1	0	1	0	2	2,011.9	1.6%	0.5%
2013	0	1	1	1	0	5	8,879.0	3.9%	2.0%
2013	1	0	0	0	0	6	10,530.3	4.7%	2.4%
2013	1	0	0	1	0	4	1,751.0	3.1%	0.4%
2013	1	0	1	0	0	1	487.0	0.8%	0.1%
2013	1	0	1	1	0	3	25,071.8	2.3%	5.6%
2013	1	1	0	0	0	11	32,128.3	8.6%	7.2%
2013	1	1	0	0	1	6	15,666.3	4.7%	3.5%
2013	1	1	0	1	0	8	12,844.5	6.3%	2.9%
2013	1	1	0	1	1	2	2,414.1	1.6%	0.5%
2013	1	1	1	0	0	8	107,381.3	6.3%	24.2%
2013	1	1	1	0	1	2	1,721.5	1.6%	0.4%
2013	1	1	1	1	0	12	121,478.4	9.4%	27.3%
2013	1	1	1	1	1	4	53,249.3	3.1%	12.0%
Total						128	444,353.5	100.0%	100.0%

Table 23 contains the results of gas billing analysis after excluding facilities with only ISMs. These results are comparable to the Table 17 where all facilities are included in the analysis model. Despite removing facilities with only ISM installations, the realization rate does not change much from the overall result, although savings as a percent of pre-NAC has increased from ~8% to ~9%. The precision around estimated savings does not improve for this subset mainly because of the low count of facilities included in the regression analysis and large variability of the dependent variable (weather normalized annual consumption). The sample size of the participant group decreased from 126 facilities (when we include all treated facilities) to 75 (when we exclude ISM-only facilities). Moreover, the variability in the facility sizes measured with the pre-period normalized usage increased when we removed facilities installing only ISMs measures.

Table 23: Gas Savings and Realization Rates Excluding Facilities with only ISMs

Description	Per-Premise at the Facility Level
Evaluated Annual Savings (Therms/Premise)	88.9
90% Precision on Evaluated Savings	±67%
Average Premise-level Pre-NAC (Therms)	971.1
Savings as Percent of Pre-NAC	9.15%
Number of Facilities in Participant Group	75
Number of Facilities in Comparison Group	123
Number of Premises in Participant Group	3,803
Number of Premises in Comparison Group	3,380
Total Realized Annual Savings without Interactive Adjustment (Therms)	337,958
Total Claimed Annual Savings (Therms)	397,873
Realization Rate without Interactive Adjustment	84.9%
Lighting Interactive Adjusted Savings (Therms)	4,963
Total Realized Annual Savings with Interactive Adjustment (Therms)	342,921
Realization Rate with Interactive Adjustment	86.2%

5.2.3 Benchmarking

DNV GL compared the results of multifamily gas billing analysis with other similar impact evaluations as a way to provide context around the results. We include single family evaluation results and note them where appropriate. Figure 8 includes the savings as percentage of pre-period weather normalized values of different multifamily impact evaluations. These studies only include standard income multifamily units that participated in an audit with measures that are directly installed. The measure types typically installed in these programs included insulation, air sealing, duct sealing, and some heating system replacements. Each of these studies employed a billing analysis and/or statistically adjusted engineering regression models in order to estimate program savings. While the measure types installed might not completely match those installed in the evaluated Multifamily Program and program designs may have difference, we believe these studies are useful to compare with our study results.

The EnergyWise program[12] evaluation of Rhode Island conducted in 2008 estimated gas participants' average savings rate of 11.9%. This was the highest among the three studies examined. The impact evaluation of the Multifamily Home Energy Services Program in Connecticut[13] reported program savings to be 5.2% of pre-installation normalized consumption. An evaluation of the Massachusetts single family Home Energy Services Program[14] reported a savings of 11.3% for gas participants. This current evaluation found savings with interactive to be in between the CT HES and EnergyWise studies (8.1% of pre-NAC).

Figure 8: Comparison of Evaluated Savings as a Percentage of Pre-NAC by program

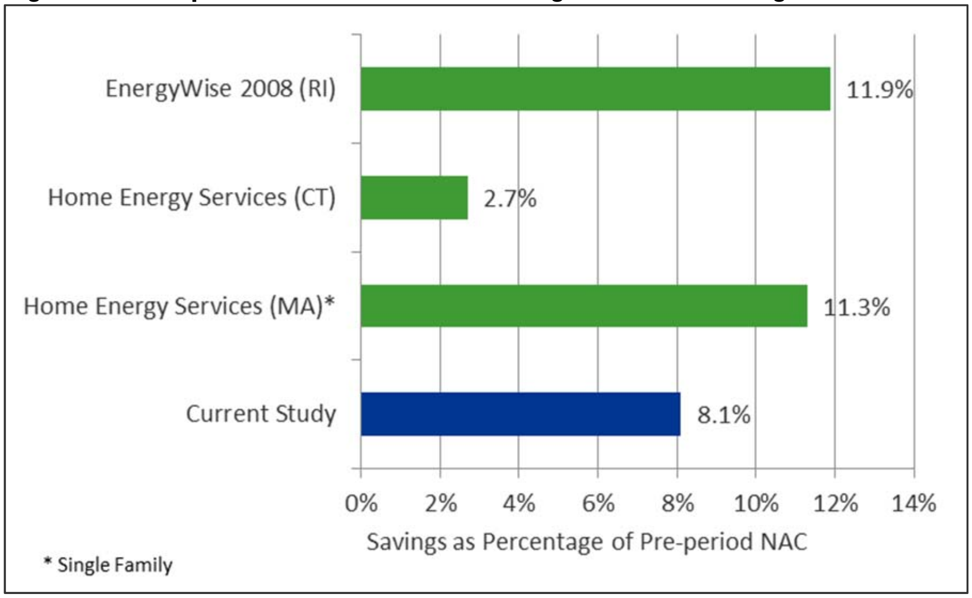


Figure 9 includes the per unit estimated savings (therms) in the two multifamily gas energy efficiency program studies. Two of these studies are the same as those presented in the figure above, one is new. The estimated savings varied considerably across different studies we looked at. The evaluation of the EnergyWise program implemented in Rhode Island in 2010 (previous was 2007) found estimated savings of 21.4 therms per unit[15]. The estimated savings observed in the Connecticut Home Energy Services Program is 56.8 therms while the Massachusetts Single Family Home Energy Services study reported the estimated savings of 140 therms. Our evaluation of multifamily gas participants in the National Grid jurisdiction estimated savings of 85.5 therms per premise.

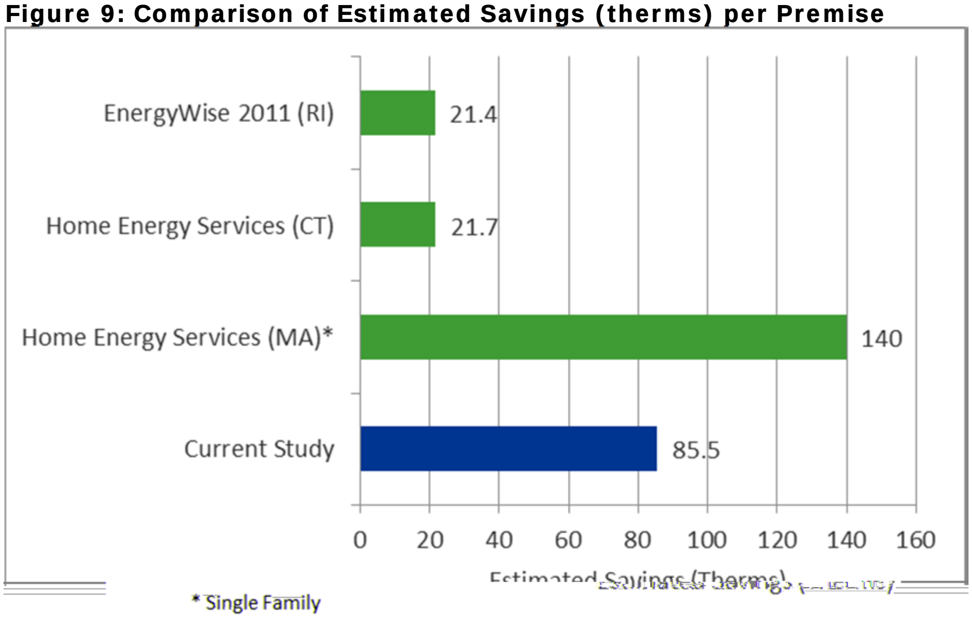
12 http://www.rieermc.ri.gov/documents/evaluationstudies/2010/EnergyWise_Final_Report_08June_clean.pdf

13 http://www.energizect.com/sites/default/files/HES%20and%20HES-IE%20Impact%20Evaluation%20(R16),%20Final%20Report,%2012-31-14.pdf

14 HES Realization Rate Results Memo, Cadmus, June 28, 2012, page 4.

15 http://www.rieermc.ri.gov/documents/evaluationstudies/2011/RI%20MF%20Gas%20Evaluation%20-%20Final%20Report-%2012JUL2011.pdf

Figure 9: Comparison of Estimated Savings (therms) per Premise



When taken together, Figure 8 and Figure 9 suggest that the Multifamily Gas Program is performing consistent, If not better than its peers with respect to savings as a percent of consumption and better than the pack in terms of savings per multifamily premise. As suggested earlier, it is challenging to identify ideal points of comparison to benchmark on. However, as a whole there is sufficient evidence to suggest that the Multifamily Program is influencing participant consumption as well, if not better than, the other programs examined.

6 CONCLUSIONS AND RECOMMENDATIONS

In this section, we review the electric conclusions and recommendations followed by gas.

6.1 Electric Conclusions

6.1.1 Conclusions

The Multifamily Program is producing electric savings, though much less than estimated in the tracking system. Our estimate of savings from the 2013 program year is 3,558,796 kWh with a precision of ±49.3 at the 90% confidence interval. This result provides a realization rate of **24.4%**. This is the estimate produced by the facility level savings analysis, which we believe provides the most reliable estimate of impacts. We found no substantial difference in results when analyzed at the premise level or when examined by facility size (number of premises in each facility) or housing type (apartment vs condominium). In fact, our results were largely consistent and stable across most of the sub-samples examined.

The exception to this was when we looked at savings by commercial versus residential bill rates. In that assessment, it became apparent that program savings are primarily driven by activity in premises with commercial rates where savings are considerably higher than savings among residential rates. In fact, our savings estimates among residential meters are not statistically significant as evidenced by a particularly poor precision around that estimate.

Given the predominance of lighting in the program, we examined the savings inputs for these measures as part of trying to understand possible drivers of the realization rate. Some limitations in tracking data constrained this exercise and we focused primarily on lighting installed in dwelling units as that sub segment comprises the vast majority of program impacts. Unfortunately, from what we were able to analyze and review, the assumed wattages and hours of use appear reasonable. There are a substantial number of lighting installations in dwelling units for which we were unable to ascertain installation location. These installations were harder to assess although there is some evidence that the assumed operating hours among these installations may be inflated.

6.1.2 Recommendations

The following recommendations rest upon the activities undertaken as part of this study. Some of these recommendations may already be planned or underway as part of ongoing program improvements.

- **Regularly enter the physical location of installed lighting.** The HOU Study cited earlier in this study provides a rich basis for assessing the operating hours in the tracking system for installed lighting. To fully maximize the ability to make this comparison, we recommend that the physical location of the installed lighting be regularly entered in either the tracking system Location Text field or other field for this purpose.
- **Consider other evaluation methods when predominate savings is from lighting.** As indicated earlier, the vast majority (92%) of program electric savings is lighting savings. Lighting savings can be very difficult to find in a billing analysis due to its relatively low savings signature. In this study, this is further compounded by the installation of nearly equal amounts of LED and CFL technologies. We also note that this billing analysis is not providing consistent results as compared to other lighting studies. We recommend that the Program Administrators consider examining lighting through a more granular approach in the near future. This approach might include phone surveys or on-sites to further check the savings estimates produced via the billing analysis.

- **Perform a small sample of inspections to ensure accurate tracking of measure locations, quantities and pre-existing conditions (when possible), along with verification of account to facility mapping.** We recommend the PAs consider performing reconnaissance inspections of a small sample of participating facilities. The goal of this effort would be to perform a visual review of installed measures, their operating conditions and any evidence of pre-existing technologies. This effort could then be used to inform any needed second efforts to further confirm any concerns or it may be an end to itself to confirm that installations and their operating conditions are consistent with tracked activity.

6.2 Gas Conclusions

DNV GL performed the multifamily gas billing analysis using several specifications. Our final estimate of program level impacts is 383,129 Therms, which does not include interactive effects. This result is accompanied by a realization rate of **86.2%** and a precision of ±64.1% at 90% confidence interval. Subsequent runs of the analysis done with various exclusions in place (i.e., premises with usage spikes, short bill intervals, or long analysis periods) provided results that are generally higher but still largely consistent with the base analysis result of 383,129 Therms.

We also analyzed program impact by including interactive effects, and separating premises based on business sector, ownership type, and size. The savings estimate for commercial bill rates is considerably higher than savings estimated for residential facilities. The difference-in-difference results found the realization rate of 127.1% for commercial facilities, whereas the realization rate is only 40.0% for residential facilities (with interactive). The impact results also vary when facilities are divided by ownership type, though not as significantly. The realization rates for apartments facilities is 109.7%. However, it is 70.4% for facilities that have condominiums. Finally, when facilities are divided by unit size, smaller facilities experienced the realization rate of 57.2%, whereas the larger facilities' realization rate is 91.7%.

7 APPENDIX A IMPACT METHODOLOGY

This appendix provides the approach and equations used in the two-stage billing analysis billing analysis.

7.1.1 Stage 1: Site-level Modeling

The full model specification of the site level modelling for electric analysis:

$$\boldsymbol{E_{im} = \mu_i + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \varepsilon_{im}}$$ ---- Equation (1a)

Similarly, the full model specification of the site level modelling for gas analysis:

$$\boldsymbol{E_{im} = \mu_i + \beta_H H_{im}(\tau_H) + \varepsilon_{im}}$$ ---- Equation (1b)

where:

E_{im}	Average electric consumption per day for participant *i* during billing period *m*
μ_i	Base load usage (intercept) for participant *i*,
$\boldsymbol{H_{im}(\tau_H)}$	Heating degree-days (HDD) at the heating base temperature τ_H
$\boldsymbol{C_{im}(\tau_C)}$	Cooling degree-days (CDD) at the cooling base temperature τ_C,
β_H	Heating coefficient, determined by the regression,
β_C	Cooling coefficient, determined by the regression,
$\boldsymbol{\tau_H}$	Heating base temperatures, determined by choice of the optimal regression,
$\boldsymbol{\tau_C}$	Cooling base temperatures, determined by choice of the optimal regression, and
$\boldsymbol{\varepsilon_{im}}$	Regression residual.

Rather than forcing the same degree-day base temperature on all of sites used in this study, we estimated consumption across a range of heating and cooling degree day bases. CDD bases covered 64°F to 84°F while HDD bases covered 50°F to 70°F.

Please note that electric consumption analysis includes three different models: 'heating and cooling,' 'cooling only,' 'heating only,' and 'baseload only' models. Whereas, gas consumption analysis includes two different models: 'heating only,' and 'baseload only' models.

For each model estimated, we chose the best cooling and heating degree base for each site based on the individual R-squared and used an F-test to determine which model specification was superior We then examined the distributions of cooling and heating base temperatures from the 'best' model to determine if the optimal degree day base temperature was on the border. If so, we re-estimated the models using the median base temperatures.

We then calculated normalized annual consumption using the parameter estimates from the best model selected for each site. Normalized annual consumption (NAC) is calculated with the help of parameters estimated from site-level regression modelling (see Equation 2). Weather normalized annual consumption is particularly important for application of billing results to development of deemed unit savings estimates that can be used for program planning and administration.

Normalized Annual Consumption for calculated as follows:

For Electric consumption analysis: $\boldsymbol{NAC_i = (365.25 \times \hat{\mu}_i) + \hat{\beta}_H H_0 + \hat{\beta}_C C_0}$ ---- Equation (2a)

For Gas consumption analysis: $\boldsymbol{NAC_i = (365.25 \times \hat{\mu}_i) + \hat{\beta}_H H_0}$ ---- Equation (2b)

Where:

NAC_i	Normalized annual consumption for customer i,
H_0	Average ten-year heating degree days calculated at the optimal heating base temperature $\hat{\tau}_H$ for participant i,
C_0	Average ten-year cooling degree days calculated at the optimal cooling base temperature $\hat{\tau}_C$ for participant, and
$\hat{\mu}_i, \hat{\beta}_H, \hat{\beta}_C$	Baseload and heating parameter estimates from the site-level models.

7.1.2 Stage 2: Difference-in-Differences

The second stage follows a difference-in difference method that compares the change in the average normalized consumption of the participant group during pre- and post-program period with the change in usage during the same period for the comparison group.

The difference-in-differences approach is a simple, robust approach to measuring program-related savings. The approach compares normalized annual consumption between the pre- and post-installation periods for both the participants and the comparison groups. The participant group pre-post difference captures all changes between the two periods including those related to the energy efficiency program. The comparison group captures all changes with the exception of those related to the efficiency program. Removing the non-program differences, as represented by the comparison group difference, from the treatment difference produces an estimate of the program's isolated effect on consumption.

The difference-in-differences method has the following structure:

$\boldsymbol{\Delta NAC_i = \alpha + \beta T + \varepsilon_i}$ ---- Equation (3)

where

ΔNAC_i	=	Pre-post difference in normalized annual consumption for household *i*;
α	=	Intercept
T	=	Treatment indicator (value of 1 if Participant and 0 otherwise)
β	=	Treatment effect, impact of efficiency program in energy savings
ε	=	error term

The coefficient, β_k, associated with difference-in-difference is the primary interest of our evaluation. The coefficient also gives the standard errors and statistical significance of the saving estimates. Standard errors can be used to calculate confidence intervals of saving estimates and test statistical hypothesis.

8 APPENDIX B MEMO OF INITIAL BILLING ANALYSIS RESULTS AND FINDINGS

Memo to:
Bob Wirtshafter, EEAC Consultant
Kim Crossman, National Grid
Beth Delahaij, National Grid
Christine Hastings, Eversource
Monica Cohen, Columbia Gas
Gail Azulay, Cape Light Compact

Copied to:
Scott Reeves, Cadmus
Sami Khawaja, Cadmus

Memo No: 001A
From: Energy
Date: October 5, 2015

Prep. By: Thomas Ledyard, DNV GL
Ken Agnew, DNV GL

This memo serves to summarize the findings to date of the multifamily impact study, provide context around these results and provide considerations, takeaways and next steps.

The table below provides the results of the two-stage, account-level, difference-of-differences modelling approach for energy consumption analysis using a panel dataset combining consumption and weather. Two electric utilities and three natural gas utilities were able to be included in this analysis after data cleaning and editing procedures. This table shows the number of participating accounts, evaluated savings per account and the precision around the evaluated savings estimate. This is followed by the pre normalized annual consumption (Pre-NAC), evaluated savings as a percent of Pre-NAC, and the tracking savings per account in our analysis. The final two columns show the realization rate and tracking savings as a percent of Pre-NAC.

PA	N	Evaluated Savings per Participant	Precision	Pre-NAC	Savings as Percent of Pre-NAC	Track Savings	Realization Rate	Tracking Savings as % of Pre-NAC
Electric (kWh)								
National Grid	8,759	177.9	±86%	6,350	3%	716	25%	11%
Eversource-E	2,842	314.7	±77%	5,773	6%	1,231	26%	21%
Overall	11,655	211.0	±62%	6,214	3%	845	25%	14%
Natural Gas (Therms)								
Columbia	125	32.1	±104%	531	6%	77	42%	14%
National Grid	1,607	13.9	±58%	656	2%	55	25%	8%
Eversource-E	356	58.5	±70%	742	8%	67	88%	9%
Overall	2,088	25.3	±47%	664	4%	59	43%	9%

We do not recommend the Program Administrators use these results for planning purposes. We suggest this as there are several reasons why this analysis was not successful.

- While it has advantages, performing our analysis at the account level exacerbated the challenge of knowing if those accounts in the analysis adequately represented the population. This is a source of potential error that is impossible to avoid in any multi-family analysis but is more difficult to fully assess without the facility-level consideration.
- The number of accounts that made it into our final analysis was very low for some PAs and this further highlights the issue of representativeness. The high attrition rate was caused by a

combination of our ability to match billing data, get sufficient data to model and successfully model those sites with sufficient data.

- Even for PAs with tracking data at the premise level, there was limited relationship between the tracked savings and savings from the consumption analysis. This lack of relationship drives particularly poor realization rates and suggests underlying issues in aligning consumption with treated space.

Concurrent with this analysis, Cadmus performed a Low Income gas billing analysis at the facility level that generated meaningful results. This approach used PRISM models performed at the facility level, whereas our effort attempted to discern impacts at the account level. In addition to the difference in unit of analysis, it is essential to note that the measure mix installed and evaluated in the low income program was much different than the measure mix installed in the standard income program. The table below shows the portion of the population in each program that installed the four key gas savings measures of air sealing, insulation, heating system replacements and water heater replacements. In general, the low-income program achieved a higher level of tenant cooperation and applied these measures to a larger percentage of overall space in the buildings.

The Low Income Multifamily Program has a much more comprehensive installation mix at participants than the standard Multifamily Program and includes system replacements (space heating, water heating). We believe the combination of higher impact measures and facility level analysis helped the Low Income impact approach be more successful than the standard Multifamily Program impact effort. We also note that unlike most electric measures in the standard income multifamily program (e.g., lighting), the gas measures installed in the low income program are primary users and drivers of gas consumption, thereby making it easier to identity impacts.

Measure	National Grid		Eversource - E		Columbia	
	LI	Std	LI	Std	LI	Std
Air Sealing	72%	83%	75%	55%	80%	45%
Insulation	61%	20%	79%	43%	68%	33%
Heating System Replacement	55%	-	25%	-	41%	1%
Water Heater Replacement	58%	-	N/A	-	30%	-

Given the shortcomings we have experienced in the account level analysis work and despite some the differences in measure types installed, we believe the multifamily impact analysis requires an approach similar to that undertaken in the low income impact analysis. The low income approach of assessing savings at the facility level was largely successful, although we again note that the anticipated level of savings as a fraction of consumption is higher for low income than standard income. Despite this, performing this analysis where accounts can be confidently and accurately aggregated to a facility level is expected to address some of the attrition issues as well as allow for additional inclusion criteria related to amount of facility-level data available. This should help us to understand and adjust for issues of representation.

One challenge we had with the account level analysis is that billing/consumption data at the account level might represent many different types of metering situations, including master meter, single meter or perhaps a series of dwelling units within a facility or among facilities. Our understanding and systematic placement of accounts within a known treated facility will help mitigate the effect of this issue in our analysis.

Following discussions with a working group comprised of several program administrators and an EEAC representative, it was determined that the issues and challenges encountered in the account level analysis warranted the close of that effort and a change in approach. This new approach will focus on a facility level billing analysis for National Grid. National Grid is the ideal candidate for this effort as they carry facility level identifiers on all unique accounts located within the treated facility. Building up to a facility level is expected to allow a better understanding of which facilities to include in the analysis and which are not.

We also note that National Grid has had previously successful billing analyses performed on this participant group and achieved a reasonable precision in the low income billing analysis. Although there is no guarantee a billing analysis will be conclusive, National Grid provides the greatest likelihood of success.

We anticipate the next steps in this project to be:

1. Convene a meeting with National Grid, Eversource – E, Cape Light Compact, Columbia Gas, Cadmus and the EEAC Consultant to review and discuss this memo, collectively understand the process that will be used in the next phase of this evaluation effort, and approve that process.
2. Schedule regular meetings of this subgroup to review progress, findings and challenges as the new analysis is performed.
3. Provide a schedule of the study effort and planned deliverables.
4. Provide a draft report of the National Grid results including methods, key findings and recommendations.

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.