Final

2010 Net-to-Gross Findings: Home Energy Assessment

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1. Executive Summary

This report summarizes the net-to-gross (NTG) findings for the 2010 Residential Conservation Services (RCS) and Gas Weatherization programs, collectively referred to hereafter as the Home Energy Assessment program. The following companies, collectively referred to as the Residential Retrofit Evaluation Team, conducted this research: The Cadmus Group Inc. (Cadmus), Opinion Dynamics, Navigant Consulting (Navigant), Itron, and Energy and Resource Solutions (ERS).

This report has been prepared for the following program administrators (PAs): NSTAR, National Grid, Columbia Gas, Unitil, Cape Light Compact, Berkshire Gas, New England Gas, and Western Massachusetts Electric Company (WMECO).

Since the early 1980s, the RCS and Gas Weatherization programs have been active in Massachusetts, targeting all non-low-income residential customers living in single-family houses or multifamily buildings with four or less units. The programs focus on identifying energy-saving opportunities using home energy audits. While the audits determine whether customers would benefit from program incentives to install significant measures (such as insulation [attic, wall, floor, etc.], water heaters, and heating systems), the audits also provide an opportunity to perform air sealing and directly install CFLs and programmable thermostats. The programs' primary goal is to achieve significant energy savings by promoting a whole-house approach through education, incentives, and financing options for gas and electric measures; the programs target all cost-effective, energy-saving improvements.

The NTG values provided in this report are statewide estimates and include the following components:

- **Freeriders (FR)**: Program participants receiving free or incented measures, who would have installed the same measures in the program's absence; FRs reduce savings attributable to the Home Energy Assessment program.
- **Participant Spillover (PS)**: Additional savings generated by customers' decisions to invest, without the assistance of program incentives, in additional efficiency measures or activities due to their program participation; PS increases savings attributable to the program.
- **Nonparticipant Spillover (NPS)**: Customers installing program-qualifying measures independently of the program, but influenced to do so by program education and marketing efforts; NPS increases savings attributable to the program.

The NTG value combines these components as follows:

$$NTG = 1 - FR + PS + NPS$$

NTG Background

While commonplace, NTG analysis remains somewhat controversial in the demand side management (DSM) industry. Consequently, energy-efficiency (EE) stakeholders across the

country handle NTG differently. For example, as of 2008, regulators in 15 states simply assumed freeridership and spillover offset one another in determining program cost-effectiveness.[1] Conversely, California requires use of deemed FR and PS values with little or no recognition of NPS. Several northeastern states, including Connecticut, Massachusetts, New York, and Vermont, require estimation of all major NTG components.

The alternative, inconsistent regulatory treatment of NTG primarily arises from the difficulty of estimating freeridership and spillover, and the lack of industry-wide consensus on how best to estimate these values. The industry's most common NTG estimation methods include:

- ***Customer Self-Reports***, where surveys determine whether participants are FRs or exhibit spillover behavior, and whether nonparticipants are influenced by programs to install program-qualifying measures. This approach is also known as the "stated preferences" method.
- ***Customer Site Visits***, employed to adjust customer self-reports with actual field findings. These efforts can be very expensive due to costs associated with scheduling, travel, and physical verification.
- ***Statistical Market Share Modeling***, where survey (and potentially site visit) data and customers' choices are modeled in a manner "revealing" rather than "stating" freeridership and spillover. Most commonly, this method uses discrete choice models.
- ***Trade Ally/Market Actor Research***, designed to gather freeridership and spillover information from the perspectives of market actors or through analysis of market data.

Each of these approaches exhibit strengths and weaknesses, and selecting one approach over another can produce significantly different results. Thus, when time and evaluation funds permit, the preferred method employs multiple approaches to properly attribute freeridership and spillover for DSM programs.

Recognizing these issues, we have designed an NTG evaluation approach addressing the 2010–2012 period that obtains NTG estimates from complementary approaches while working within resource constraints, which requires staggered implementation of the various approaches over time.

2010 NTG Methodology

The 2010 Home Energy Assessment program NTG estimates are based on three combined approaches:

1. ***Customer Self-Reports.*** Customer self-reported FR and PS through surveys of 2010 RCS (electric) and Gas Weatherization participants. As shown in Table 1, this analysis considered all program measures. A survey of 1,200 electric and 400 gas participants informed the analysis.

[1] *Assessment of Energy and Capacity Savings Potential in Iowa Volume 2, Appendix G: Attribution of Energy Savings: An Assessment of the Net-to-Gross Ratio Issue*, prepared for the Iowa Utility Association by Quantec, et al. February 15, 2008.

Table 1. Home Energy Assessment Program Measures

Measure Category	Measure	RCS	Gas WX
CFL Direct Installs	CFL	√	√
Direct Installs	Air Leak Sealing	√	√
	Programmable Thermostat	√	√
Incented Measures	Heating System	√	
	Insulation	√	√
	Duct Insulation and Sealing		√
	Refrigerator	√	
	Water Heater	√	

2. ***Statistical Market Share Modeling.*** Discrete choice modeling of FR and NPS used 400 Gas Weatherization participant and 400 nonparticipant surveys. This analysis did not include the 1,200 electric participants surveyed in fall 2010, as the questionnaire used was not designed for these models. The 2010 NTG analysis also focused on insulation and duct sealing/duct insulation (collectively referred to as insulation), the most important measures in terms of savings.

3. ***Trade Ally Research.*** Interviews with more than 30 insulation contractors focused on participant and nonparticipant insulation installations, and attribution of self-reported nonparticipant jobs as spillover.

Final participant FR, PS, NPS, and NTG values are composite estimates (rather than a simple average) of the various research methods employed. The estimates were developed using a triangulation process, incorporating our experience, professional judgment, and understanding of the programs.

Table 2 summarizes the applicable methodologies available by measure and NTG component for the 2010 Home Energy Assessment (RCS and Gas Weatherization) program.

Table 2. 2010 RCS and Gas Weatherization NTG Component Estimation by Measure

Measure Category	Measure	Participant Freeridership	Participant Spillover	Nonparticipant Spillover
CFL Direct Installs	CFL	CSR	CSR	NA
Direct Installs	Air Leak Sealing	CSR	NA	NA
	Programmable Thermostat	CSR	NA	NA
Incented Measures	Heating System	CSR	NA	NA
	Insulation	CSR, DC	CSR	DC, ICSR
	Refrigerator	CSR	NA	NA
	Water Heater	CSR	NA	NA
CSR: Customer Self Report				
DC: Discrete Choice				
ICSR: Insulation Contractor Self Report				
NA: Not Available				

Additional information relating to the composite estimates is provided in the discussion below.

- **FR Estimation for Identical Electric and Gas Program Measures**. Although FR was estimated by measure separately for RCS and Gas Weatherization, findings were aggregated when measure-specific findings were determined to be not statistically different across the survey samples. Combining the estimates made sense intuitively, as FR (as an example, for CFLs), would not logically differ based on whether participants had gas heat (Gas Weatherization) or any other type of heating system (RCS).
- **Insulation FR Estimation**. For insulation, the composite FR estimate of 20% was based on the average of the customer self-report (10%) and the discrete choice FR analyses (29%).
- **PS Estimation**. The 2010 RCS survey had a very general, non-measure specific PS question battery. In the 2011 Gas Weatherization survey program, participants were asked about several specific types of measures they might have installed on their own, including two major measures in terms of Gas Weatherization savings: CFLs and insulation. These PS estimates were applied to electric CFL and insulation participants, respectively. No other measures received PS credit for the 2010 Home Energy Assessment program.
- **NPS Estimation**. NPS is estimated only for insulation. The NPS estimate of 50% determined through the discrete choice analysis was used as the final, composite estimate. Although the contractor self-reports show NPS at approximately 75%, we chose to be more conservative given that these NPS estimates are somewhat high. No other measures received NPS values for the 2010 Home Energy Assessment program.

Results

Table 3 presents NTG findings, by measure and overall, for the 2010 Home Energy Assessment program.

Table 3. 2010 RCS and Gas Weatherization NTG Findings

Measure Category	Measure	Participant Freeridership	Participant Spillover	Nonparticipant Spillover	NTG
CFL Direct Installs	CFL	22% ± 2%	19% ± 5%	0%	97%
Direct Installs	Air Leak Sealing	7% ± 3%	0%	0%	93%
	Programmable Thermostat	11% ± 5%	0%	0%	89%
Incented Measures	Heating System	28% ± 5%	0%	0%	72%
	Insulation	20%*	8% ± 2%	50% ± 5%**	138%
	Refrigerator	5% ± 5%	0%	0%	95%
	Water Heater	25% ± 10%	0%	0%	75%
Overall		18%	7%	23%	112%

*A confidence interval around the insulation FR is not shown since it is a composite of customer self-report and discrete choice methods

**The confidence interval of +/- 5% shown for non-participant spillover for insulation only reflects the sampling error associated with the value, however, there is also significant level of uncertainty associated with the size of the

population of eligible households used to establish the estimate which is not reflected in the sampling error.

It is critical to interpret the results below correctly. With this intention, the evaluation team offers the following four caveats.

1. As noted above, uncertainly exists regarding all estimates of NTG. While the evaluation team has provided the most accurate point estimate of NTG possible given available information, it is important to recognize that the choice of methods and their implementation is somewhat subjective, resulting in uncertainty as to the "true" NTG values.[2]

   Let's consider insulation, where we estimate an NTG of 138%. If, however, we use the insulation contractor NPS results instead of the discrete choice model estimate, NPS would be 75% instead of 50%, raising the NTG to 163%. Conversely, it is also possible that the insulation NTG estimate is high. A recent meta-evaluation conducted by a colleague collected NTG estimates from other studies and found an average of 63% for insulation for similar programs.[3] It is not clear whether participant spillover, let alone nonparticipant spillover was factored into these evaluation findings. The wide variance in the estimates—perhaps as much as ± 50% across all measures in the program—is why some jurisdictions assume that freeridership and spillover cancel out and use an NTG value of 100% to evaluate program cost-effectiveness.

   We present confidence intervals for the Customer Self-Report estimates in Section 3 and discuss non-participant spillover uncertainty in Section 4. We present only a rough confidence interval for the NPS estimate due to the fact that the distribution of insulation levels and other factors that define the size of the eligible population are unknown, and the data collection necessary to determine the eligible population was beyond the scope of the 2010 Home Energy Assessment evaluation. We expect to be able to quantify the eligible population in future evaluations through the analysis of data collected from residential site visits.

2. The NTG values determined through this effort are applicable to the RCS and Gas Weatherization programs in Massachusetts. For example, one should not use these estimates for the Low Income or Multifamily programs given the very real differences in market actors and energy-efficiency decision making in the segments targeted by those programs.

3. As the designs of the RCS and Gas WX programs change and the energy-efficiency knowledge and practices of market actors evolve, we expect the NTG results to change too. For example, in 2010 some of the PAs were still providing insulation incentives without an audit, but that practice has been terminated. Additionally, we anticipate that

[2] This uncertainty is very different—and much larger—than the confidence or error bounds for estimated parameters within a given approach. For example, we report the sample-size based error bounds for the self-reported freeridership estimates in Chapter 3, but these are quite small relative to the methodology and scoring choices made by energy-efficiency professionals.

[3] *Home Energy Performance Electric Program Evaluation—PY2*. Prepared for Ameren Illinois by The Cadmus Group Inc. / Energy Services, March 2011.

the 2011 or 2012 evaluations will attempt to estimate PS and NPS estimates for measures where they were not available from the 2010 evaluation.

4. The overall NTG of 112% is a weighted average of the measure-specific NTG values listed in Table 3 based on the distribution of installed measures statewide in 2010. The overall NTG will differ for each PA based on their specific distribution of installed measures in 2010. Likewise, any application of the NTG estimates for planning purposes should consider the implication of changes in program design or measure distribution over time.

2. Introduction

Overview

The 2010 Home Energy Assessment program NTG estimates are based on three combined approaches:

1. ***Customer Self-Reports.*** Customer self-reported FR and PS through surveys of 2010 RCS (electric) and Gas Weatherization participants. As shown in Table 4, this analysis considered all program measures. A survey of 1,200 electric and 400 gas participants informed the analysis.

Table 4. Program Measures

Measure Category	Measure	RCS	Gas WX
CFL Direct Installs	CFL	√	√
Direct Installs	Air Leak Sealing	√	√
	Programmable Thermostat	√	√
Incented Measures	Heating System	√	
	Insulation	√	√
	Duct Insulation and Sealing		√
	Refrigerator	√	
	Water Heater	√	

2. ***Statistical Market Share Modeling.*** Discrete choice modeling of FR and NPS used 400 Gas Weatherization participant and 400 nonparticipant surveys. This analysis did not include the 1,200 electric participants surveyed in fall 2010, as the questionnaire used was not designed for these models. The 2010 NTG analysis also focused on insulation and duct sealing/duct insulation (collectively referred to as insulation), the most important measures in terms of savings.

3. ***Trade Ally Research.*** Interviews with more than 30 insulation contractors focused on participant and nonparticipant insulation installations, and attribution of self-reported nonparticipant jobs as spillover.

This chapter briefly describes each of these methods. Subsequent chapters and appendices provide additional details, algorithms, and survey instruments. As noted above, customer surveys were used for both the customer self-report and discrete choice methods. We therefore conclude this chapter with a discussion of the customer survey sampling methodology, sample disposition, and related issues around these data in this introductory chapter as the results apply to both subsequent chapters.

Customer Self-Reports

We designed survey questions to determine why customers installed given measures and the program's influence over those decisions. For FR, the goal of the survey was to establish the decision makers' possible actions in the program's absence. The following core FR questions addressed this question:

- Did the participant plan to install the measure prior to learning about the program?
- Would the participant have installed the same quantity of measures without the program?
- In the program's absence, when would the respondent have installed the measures?
- What was the self-assessed likelihood the participant would have installed free or incented program measures outside the Home Energy Assessment program?

The PS included the three following primary question areas:

- Since participating in the program, did the participant install additional energy-efficient equipment or services not rebated through a PA program?
- What additional energy-efficient equipment did participants install (and how much or how many)?
- How much did the program influence the participant's decision to install additional energy-efficient equipment in their home?

To calculate FR and PS, we divided measures offered by the Home Energy Assessment program into three categories, as defined in Table 4 above, with each measure category requiring slightly different survey skip patterns and scoring algorithms.

After asking customers about their plans, quantities, and timing, estimation of FR and PS focused on customers' self-reported likelihood of FR and PS. As noted, a critical part of self-report freeridership methodologies is assigning how likely a participant would have been to install measures in a program's absence. If survey participants reported they were highly likely to obtain the measure in the program's absence (defined as an 8, 9, or 10 response of on a scale of 0 to 10, where 10 was "extremely likely" and 0 was "not at all likely"), we identified the action as program freeridership. If a respondent provided a 5 to 7 influence rating, they were classified as partial FRs. Respondents with a 4 or less rating were not attributed as reported freeridership for the Home Energy Assessment program.

Similarly, for PS we obtained the program's relative influence on respondents' decisions to pursue additional measures and obtain energy savings. If survey respondents indicated their participation in the Home Energy Assessment program highly influenced their decision to take EE actions outside the program (again, defined as an 8, 9, or 10 response on a scale of 0 to 10, where 10 was "extremely influential" and 0 was "not at all influential"), we identified the action as PS. If a respondent provided a 5 to 7 influence rating, they were classified as partial spillover. Respondents with a 4 or less rating were not attributed as reported spillover to the Home Energy Assessment program.

Discrete Choice Analysis

The key distinction between self-report (stated preference) and discrete choice (revealed preference) approaches is that the latter method does not use the "relative likelihood" questions described above. Rather, the model's parameters and their relative influence on the probability of adopting measures drives freeridership and spillover estimates.

Discrete choice models assume individuals base decisions on a desire to maximize personal utility functions. Broadly interpreted, a utility function may consider not only direct financial interests, but also more idiosyncratic concerns, such as aesthetics or conservation ethics. To account for such a wide variety of factors, each individual's utility function with respect to a given set of choices—$j = 1, 2, \ldots, J$ —is composed of two distinct parts,

$$U(j) = V(j) + \epsilon(j).$$

The first part, $V(j)$, represents the portion of the individual's utility knowable to the researcher, in that it is a function of traits the researcher has observed. For instance, insulation, (j), is a function of:

- Age
- Family size
- Home ownership (1 if customer owned the home, 0 otherwise)
- Audit (1 if customer received an audit, 0 otherwise)
- Dollar value of insulation incentives
- Program awareness

As the second component of the individual's utility, $\epsilon(j)$, is considered the portion for which researchers cannot account, it is modeled as random. The different types of discrete choice models can largely be distinguished by their different assumptions regarding the joint distribution of $\epsilon(j)$.

For a given specification of explanatory variables believed to influence a customer's decision, the function's parameters, $\beta_{k,j}$, are fitted to a dataset via maximum likelihood or a similar method. Based on the fitted parameters, a researcher can estimate the probability of an individual's choosing one option or another as a function of his or her explanatory variables.

The Gas Weatherization and nonparticipant surveys obtained demographic and attitudinal information, as well as purchase information and program awareness questions, for participants and nonparticipants. Therefore, the fitted parameter values estimated the effects of program awareness, measure cost, etc., on consumers' insulation decisions. To determine the different measure adoption levels that would have occurred in the program's absence, we input (to the fitted model) consumer data with several variables altered to describe choices consumers would have faced had the program not existed (e.g., program awareness was set to zero to measure NPS, and all program variables were set equal to zero to measure FR).

Insulation Contractor Surveys

The evaluation team fielded a telephone survey with 33 home improvement (insulation) contractors. Of contractors surveyed, 24 actively participate in the Home Energy Assessment program, seven have participated but are not currently active, and two install insulation completely outside the program. Survey responses formulate a picture of how contractors view the Home Energy Assessment program, reveal barriers to customer and contractor participation, and provide insights into the program's potential market effects on the home improvement market.

The survey instrument contained modules and questions specifically directed at either participating or nonparticipating contractors. Contractors were considered: active in the program if they received an incentive for any residential retrofit weatherization projects during the last two years; inactive if listed as a participating contractors on the PA Webpage, but have not received an incentive in the last two years; and nonparticipating if they have never participated in the program.

Participating contractor questions explored the prevalence of customers installing insulation outside the program (NPS) by discussing the following key issues:

- Program influence on changes in business practices
- Program influence on changes in customer awareness and installation of insulation measures
- Attribution of spillover impacts

Nonparticipating contractor questions explored NPS through the following issues:

- Business practices
- Participation barriers
- Awareness of the program
- Attribution of spillover impacts

We used a three-step process to quantify NPS. First, we examined the total number of homes contractors weatherized annually, determining the number of homes insulated outside the program that could potentially qualify as spillover. Second, we asked respondents to assess the program's influence on their business practices, and, ultimately, whether the program influenced these non-program projects. Finally, we summed the number of non-program homes impacted by contractor participation in the program and divided this by the total number of program homes to derive the final NPS estimate.

3. Customer Self-Reports

The Residential Retrofit Evaluation Team designed RCS and Gas Weatherization participant survey questions to determine why customers installed a given measure and the program's influence over those decisions.

Freeridership

To calculate freeridership, **or** the percentage of savings that would have occurred in the program's absence, we used a battery of survey questions for each measure category. Collectively, the questions estimated the influence of the Home Energy Assessment program on participants' decision-making processes, and then were used to determine the likelihood the measure would have been installed in the program's absence. Specifically, the survey asked questions related to the following freeridership aspects:

- Did the participant have plans to install the measure prior to learning about the program?
- Would the participant have installed the same quantity of measures without the program?
- In the program's absence, when would the respondent have installed the measures without the program?
- What was the self-assessed likelihood the participant would have installed free or incented program measures outside the Home Energy Assessment program?

After asking customers about their plans, quantity, and timing, the freeridership estimation focused on customers' self-reported likelihood of doing so. A critical part of the self-report freeridership methodology was assigning how likely a participant would have been to install measures in the program's absence. If survey participants reported they were highly likely to obtain the measure in the program's absence, (defined as an 8, 9, or 10 response on a scale of 0 to 10, where 10 was "extremely likely" and 0 was "not at all likely"), we identified the action as program freeridership. If a respondent provided a 5 to 7 influence rating, they were classified as a partial FR. Respondents with a 4 or less rating were not attributed to reported Home Energy Assessment program freeridership.

To illustrate how each battery of questions was used to estimate freeridership, we created a logic model diagram for each measure category. These four diagrams, depicting exactly how we estimated the percentage of freeridership for each measure, are provided at the end of this section.

Freeridership Methodology

The evaluation team developed a transparent, straightforward matrix approach to assign a score to participants, based on their objective responses to the battery of survey questions. Question response patterns were assigned freeridership scores, and the confidence and precision estimates were calculated on the distribution of these scores.

The response patterns and scoring weights remain explicit; so they can be discussed or changed and the results shown in real time. Our approach provided other important features, including:

- Derivation of a partial freeridership score, based on the likelihood of a respondent taking similar actions in the incentive's absence.
- Use of a rules-based approach for consistency among multiple respondents.
- Use of consistency checks and open-ended questions to ensure quantitative scores matched respondents' more detailed explanations regarding program attribution.
- The ability to change weightings in a "what if" exercise, testing the response set's stability.

The evaluation team's method offered a key advantage by introducing the concept of partial freeridership. Experience has taught us that program participants do not fall neatly into freerider and non-freerider categories. For example, partial freeridership scores were assigned to participants with plans to install the measure; though, the program exerted some influence over their decision, other market characteristics beyond the program also proved influential. In addition, with partial freeridership, we could utilize "Don't Know" and "Refused" responses by classifying them as partial credit, rather than removing the entire respondent from the analysis.

Freeridership was assessed at three levels. First, each participant survey response was converted into freeridership matrix terminology. Each participant's combination of responses was then assigned a score from the matrix. Finally, all participants were aggregated into an average freeridership score for the entire measure category.

Convert Responses to Matrix Terminology

We independently evaluated each survey question's response to assess participants' freeridership level for each question. Each survey response option was converted into a value of "Yes" (indicative of freeridership), "No" (not indicative of freeridership), or "Partial" (partially indicative of freeridership).

Table 5 below lists the four CFL FR survey questions, their corresponding response options, and the value to which we converted them (in parentheses). "Don't know" and "Refused" responses were converted to "Partial" for all but the fourth question. For that question, we defined two different levels of a partial freerider and determined if a participant was unsure when they would have purchased the measure, they were unlikely to be a freerider and should receive a lower freeridership score, which is represented by a "Partial2" matrix value. This same methodology is used for both the electric participant and gas participant freeridership analysis.

Table 5. Assignments of CFL Response Options into Matrix Terminology

Before the home energy assessment did you have any CFLs installed in your home?	If you had not received free CFLs during the home energy assessment, would you have installed any CFLs on your own within the next year?	If you had not received free CFLs during the home energy assessment, would you have installed the same number or fewer CFLs than were installed?	If you had not received free CFLs from the home energy assessment, when would you have bought CFLs on your own?
Yes (Yes)	Yes (Yes)	We would have installed FEWER CFLs (No)	At roughly the same time (Yes)
No (No)	No (No)	We would have installed the SAME number of CFLs (Yes)	Within a few months (Partial1)
Don't Know (Partial)	Don't Know (Partial)	We would have installed more (Yes)	Within a year (Partial2)
Refused (Partial)	Refused (Partial)	Don't Know (Partial)	More than a year (No)
		Refused (Partial)	Don't Know (Partial2)
			Refused (Partial2)

Table 6 below lists the four Direct Install FR survey questions, their corresponding response options, and the value to which we converted them (in parentheses). “Don’t know” and “Refused” responses were converted to “Partial” for all questions. This same methodology is used for both the electric participant and gas participant freeridership analysis.

Table 6. Assignments of Direct Install Response Options into Matrix Terminology

Before learning about the Home Energy Assessment program, were you already planning to <MEASURE>?	Would you say it happened earlier than you had originally planned BECAUSE of the home energy assessment?	If the team hadn't done it, when do you think you would have done it?	If the home energy assessment team had not done it, how likely would you have been to < MEASURE >Use a scale from 0-10, where 0 is "not at all likely" and 10 is "extremely likely".
Yes (Yes)	Earlier because of the home energy assessment (No)	Within six months (Yes)	8,9,10 (Yes)
No (No)	Earlier than planned but NOT because of the home energy assessment? (Yes)	Between six months and a year (Partial)	5,6,7 (Partial)
Don't Know (Partial)	About the same time as planned? (Yes)	More than a year (No)	0,1,2,3,4 (No)
Refused (Partial)	Later than planned? (Yes)	Don't Know (Partial)	Don't Know (Partial)
	Don't Know (Partial)	Refused (Partial)	Refused (Partial)
	Refused (Partial)		

Table 7 below lists the three Insulation Incented Measure FR survey questions, their corresponding response options, and the value to which we converted them (in parentheses). "Don't know" and "Refused" responses were converted to "Partial." This same methodology is used for both the electric participant and gas participant insulation freeridership analysis.

Table 7. Assignments of Insulation Incented Measures Response Options into Matrix Terminology

Before learning about the Home Energy Assessment program, were you already planning to buy (a) new <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>?	How influential was the Home Energy Assessment program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential."
Yes (Yes)	Within six months (Yes)	0,1,2,3 (Yes)
No (No)	Between six months and a year (Partial)	4,5,6 (Partial)
Don't Know (Partial)	More than a year (No)	7,8,9,10 (No)
Refused (Partial)	Don't Know (Partial)	Don't Know (Partial)
	Don't Know (Partial)	Don't Know (Partial)

Table 8 below lists the five FR survey questions for all other incented measures, their corresponding response options, and the value to which we converted them (in parentheses). "Don't know" and "Refused" responses were converted to "Partial." This methodology is used for only electric participant incented measures that fall into the category of a heating system, refrigerator, or water heater. The gas participant survey did not contain these additional measures.

Table 8. Assignments of Other Incented Measures Response Options into Matrix Terminology

Before learning about the Home Energy Assessment program, were you already planning to buy (a) new <MEASURE>?	Were you planning to purchase a <MEASURE> with the same level of energy efficiency before you learned about the Home Energy Assessment program?	Did you purchase the <MEASURE> earlier than you had originally planned because of the rebate you received through the Home Energy Assesment program, or did the rebate not change the timing of when you purchased the <MEASURE>? That is, did you purchase it earlier…	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Home Energy Assessment program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential."
Yes (Yes)	Yes (Yes)	Because of the rebate (No)	Within six months (Yes)	0,1,2,3 (Yes)
No (No)	No (No)	Not because of the rebate (Yes)	Between six months and a year (Partial)	4,5,6 (Partial)
Don't Know (Partial)	Don't Know (Partial)	Don't Know (Partial)	More than a year (No)	7,8,9,10 (No)
Refused (Partial)	Don't Know (Partial)	Don't Know (Partial)	Don't Know (Partial)	Don't Know (Partial)
			Don't Know (Partial)	Don't Know (Partial)

Participant Freeridership Scoring

After converting survey responses into matrix terminology, we created a freeridership matrix, so the combination of each participant's responses to the six questions could be assigned a freeridership score. To create the matrix, we determined every combination of possible responses to the six survey questions, and then assigned a freeridership score of 0 to 100 percent to each combination. These matrices are provided in the results section below and are also available as logic model diagrams at the end of this chapter. Using these matrices, every participant combination of responses was assigned a score of 0 to 100 percent.

Freeridership Error Bounds

To quantify self-report error bounds, we calculated error bounds at the 90 percent confidence level for each measure category. Given the relatively large sample sizes and visual inspection of the data, the normality assumption proved robust, and we estimated confidence intervals accordingly. We found virtually all measure-level freeridership estimates fell within ±10 percent absolute precision, ensuring program-level freeridership estimates were consistent with industry standards.

We report absolute precision for the freeridership estimates calculated as follows:

$$Absolute\ Precision = 1.645 * \frac{\mathrm{SD}}{\sqrt{\mathrm{n}}}$$

Where *SD* is standard deviation of the mean freeridership estimate, *n i*s total sample size and 1.645 is the multiplier for used to obtain a 90% confidence interval about the mean.

Participant Spillover Methodology

We measured participant spillover by asking participating customers if they decided to install other efficiency measures due to their program participation. To tie these purported actions to their participation in the Home Energy Assessment program, we asked survey respondents to report the program's relative influence on their decision to pursue these additional savings. The participant spillover battery included three primary question areas:

- Since participating in the program, had the participant installed additional energy-efficient equipment or services not rebated through a PA program?
- What additional energy-efficient equipment was installed (and how much or how many)?
- How influential was the program in the participant's decision to install additional energy-efficient equipment in their home?
- Did the participant install the insulation before or after participating in the Home Energy Assessment program?

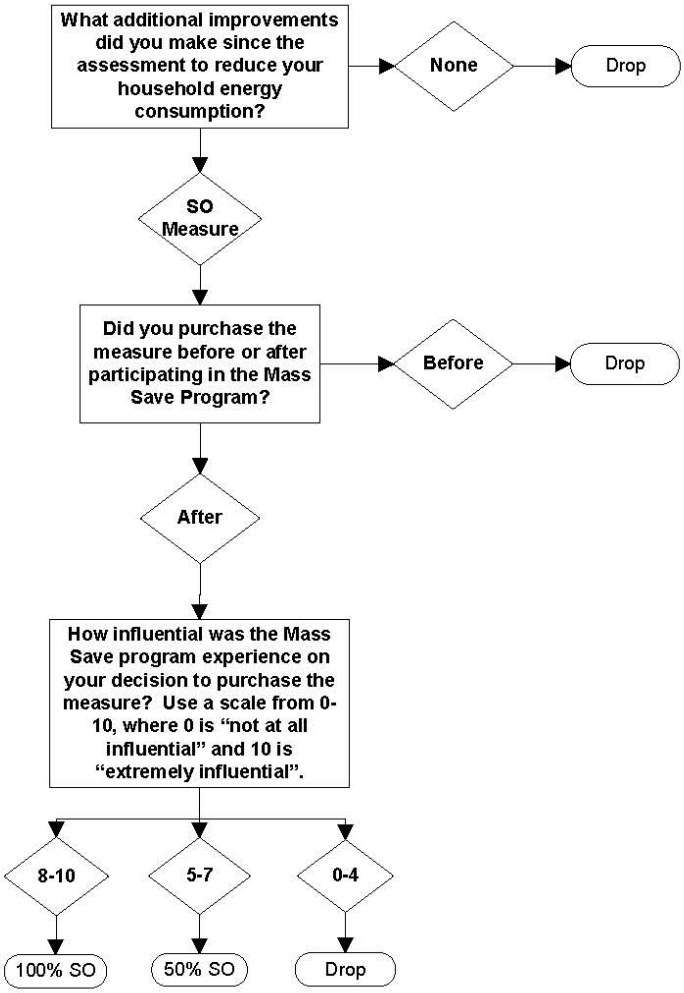
Using a process similar to freeridership, participant spillover was obtained by gauging the program's relative influence on their decision to pursue these additional measures and obtain energy savings. If survey respondents indicated their participation in the Home Energy Assessment program was highly influential in their decision to take EE actions outside the program (again defined as an 8, 9, or 10 response on a scale of 0 to 10, where 10 was "extremely influential" and 0 was "not at all influential"), we identified the action as PS. If a respondent provided a 5 to 7 influence rating, they were classified as partial spillover. If a respondent provided an influence rating of 4 or less, we did not attribute the reported spillover to the Home Energy Assessment program.

Due to the uncertainty of the efficiency and type of measure, self-report participant spillover was estimated only for CFL and insulation measures. Additionally, while the RCS electric surveys contained a spillover battery, a more robust measure-specific battery was designed for the Gas Weatherization participant survey so we relied exclusively on the results from that survey in estimating CFL and insulation measure participant spillover.

The logic model contained in Diagram 1 exhibits the process in which a respondent's CFL or insulation spillover response is included or excluded from being attributed to the Home Energy Assessment program. If a respondent purchased the additional reported measure before participating in the Home Energy Assessment program, their measure is dropped from the spillover analysis. If a respondent purchased the measure after participating in the Home Energy Assessment program and they rated the influence of the program experience as "highly influential" (8, 9, or 10 response option) in their decision to purchase the additional measure,

their additional measure is fully attributed to the program spillover. If a respondent answered 5, 6, or 7 for the influence of the Home Energy Assessment Program on their additional purchase, half of the measure is attributed to the program. If a respondent answered 0, 1, 2, 3, or 4 for the influence of the Home Energy Assessment program on their additional purchase, their measure was dropped from the spillover analysis.

Diagram 1. Assignments of Other Incented Measures Response Options into Matrix Terminology



The CFL and insulation spillover responses that are not dropped are used in the participant spillover analysis section of this report.

Spillover Error Bounds

To quantify self-report spillover error bounds, we calculated absolute precision estimates at the 90 percent confidence level for each spillover measure category analyzed.

To obtain a precision estimates for CFL spillover, we calculated the standard error of the number of spillover CFLs per respondent in the participant survey. Our 90% confidence interval is the standard error multiplied by 1.645 and divided by the estimated average number of CFL's given to each participant through the program. We gave respondents who said the Mass Save program experience was somewhat influential (5, 6, 7 rating) over their decision to purchase additional CFLs 50 percent credit for their reported spillover CFL purchases. We derived the estimated average number of CFL's given to each participant through the program from program tracking database information.

To obtain a precision estimates for insulation spillover, we calculated the standard error of the spillover scores derived as shown in Diagram 2 above. Our 90% confidence interval is the standard error multiplied by 1.645 and divided by the total number of surveyed participants that installed insulation. We gave respondents who said the Mass Save program experience was somewhat influential (5, 6, 7 rating) over their decision to install insulation outside the program 50 percent credit for their reported spillover installations.

Freeridership Analysis and Results

After conducting participant surveys, each participant's freeridership score was derived by translating responses into a matrix value, and then using a rules-based calculation to obtain the final score. In this section, we present all combinations of responses we received for each program category, and the scores assigned to each combination. The figures that follow show participant responses rarely reflected each potential combination, but tended to group around a subset of common patterns. Freeridership scores, confidence intervals, and precision estimates were calculated for each program category, based on the distribution of scores within the matrix.

CFL Freeridership Analysis

Table 9 shows the results of freeridership calculations for CFL program participants that were surveyed. We discuss in-depth freeridership analysis for each participant stream in the following sections.

Table 9. CFL Freeridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	1,000	0.23 (± 0.02)	0.25	0.21
Gas	277	0.19 (± 0.03)	0.22	0.16

Electric Participant CFL Freeridership Results

Table 10 below shows the unique response combinations from the electric participant CFL battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 10. Electric Participant CFL Freeridership Results

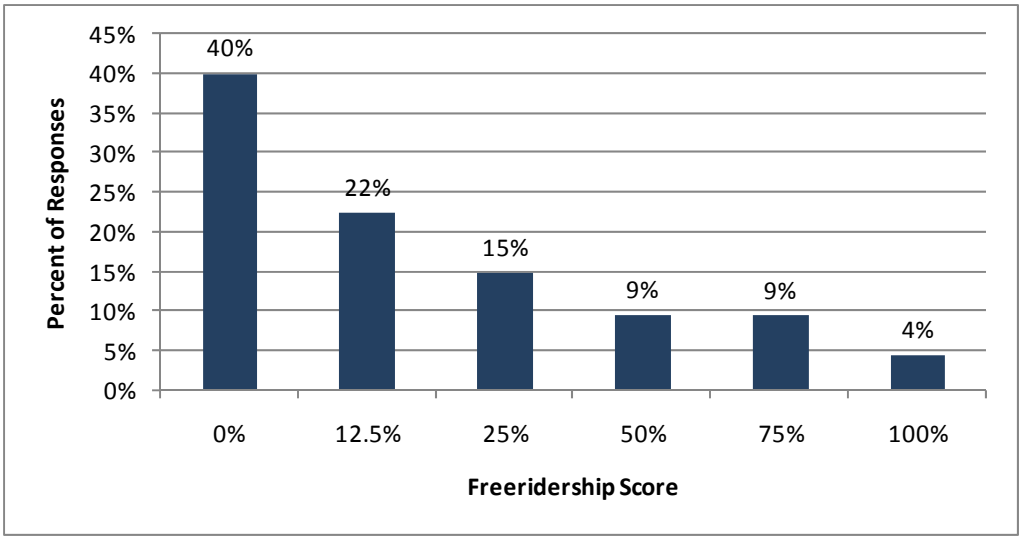
Before the home energy assessment did you have any CFLs installed in your home?	If you had not received free CFLs during the home energy assessment, would you have installed any CFLs on your own within the next year?	If you had not received free CFLs during the home energy assessment, would you have installed the same number or fewer CFLs than were installed?	If you had not received free CFLs from the home energy assessment, when would you have bought CFLs on your own?	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	43
Yes	Yes	Yes	Partial1	75%	90
Yes	Yes	Yes	Partial2	50%	72
Yes	Yes	Yes	No	0%	2
Yes	Yes	Partial	Yes	75%	1
Yes	Yes	Partial	Partial1	50%	1
Yes	Yes	Partial	Partial2	25%	6
Yes	Yes	Partial	No	0%	1
Yes	Yes	No	Yes	50%	13
Yes	Yes	No	Partial1	25%	95
Yes	Yes	No	Partial2	12.5%	204
Yes	Yes	No	No	0%	28
Yes	Partial	x	x	25%	20
Yes	No	x	x	0%	164
Partial	Yes	No	Partial1	12.5%	1
No	Yes	Yes	Yes	75%	2
No	Yes	Yes	Partial1	50%	8
No	Yes	Yes	Partial2	25%	17
No	Yes	Yes	No	0%	2
No	Yes	Partial	Partial1	25%	2
No	Yes	No	Yes	25%	7
No	Yes	No	Partial1	12.5%	18
No	Yes	No	Partial2	0%	35
No	Yes	No	No	0%	3
No	Partial	x	x	0%	16
No	No	x	x	0%	149

Three patterns appeared in the electric CFL respondents' answers to the freeridership questions:

- 205 respondents (20%) had CFLs installed in their home before the home energy assessment, would have installed CFLs on their own within the next year, and would have installed the same number of CFLs that were received through the assessment. 43 of the 205 (21%) would have bought the CFLs at the same time and are being scored as 100 percent freeriders. 90 of the 205 (44%) would have bought the CFLs within three months and are being scored as 75 percent freeriders. 72 of the 205 (35%) would have bought the CFLs within a year and are being scored as 50 percent freeriders.
- 204 respondents (20%) had CFLs installed in their home before the home energy assessment and would have installed CFLs on their own within the next year, but would have installed fewer CFLs than what was provided during the home energy assessment and would have bought the additional CFLs within a year. These respondents are being scored as 12.5 percent freeriders.
- 313 respondents (31%) would not have installed any CFLs on their own within the next year and are being scored as zero percent freeriders.

Figure 1 shows a distribution of electric participant CFL survey respondents by the freeridership score assigned to each. Approximately 40 percent of CFL survey respondents indicated no freeridership. Additionally, almost 23 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for 37 percent of respondents.

Figure 1. Distribution of Electric Participant CFL Freeridership Scores



Gas Participant CFL Freeridership Results

Table 11 shows the unique response combinations from the gas participant CFL battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 11. Gas Participant CFL Freeridership Results

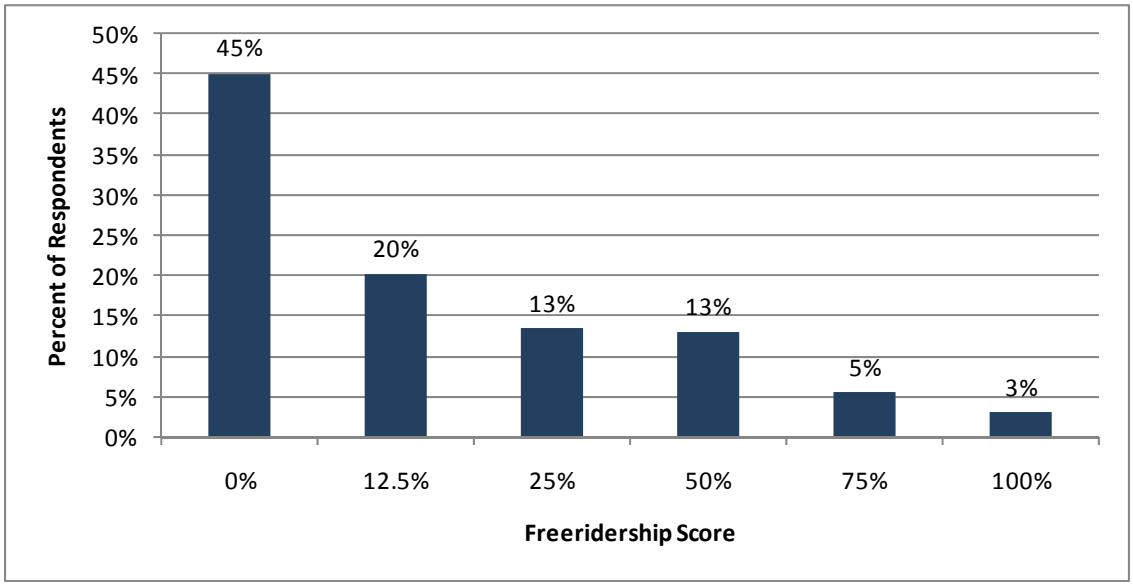
Before the home energy assessment did you have any CFLs installed in your home?	If you had not received free CFLs during the home energy assessment, would you have installed any CFLs on your own within the next year?	If you had not received free CFLs during the home energy assessment, would you have installed the same number or fewer CFLs than were installed?	If you had not received free CFLs from the home energy assessment, when would you have bought CFLs on your own?	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	8
Yes	Yes	Yes	Partial1	75%	12
Yes	Yes	Yes	Partial2	50%	27
Yes	Yes	Yes	No	0%	4
Yes	Yes	Partial	Yes	75%	1
Yes	Yes	Partial	Partial1	50%	1
Yes	Yes	Partial	No	0%	1
Yes	Yes	No	Yes	50%	5
Yes	Yes	No	Partial1	25%	23
Yes	Yes	No	Partial2	12.5%	49
Yes	Yes	No	No	0%	13
Yes	Partial	x	x	25%	7
Yes	No	x	x	0%	48
No	Yes	Yes	Yes	75%	2
No	Yes	Yes	Partial1	50%	3
No	Yes	Yes	Partial2	25%	4
No	Yes	No	Yes	25%	3
No	Yes	No	Partial1	12.5%	7
No	Yes	No	Partial1	0%	10
No	Yes	No	No	0%	3
No	Partial	x	x	0%	3
No	No	x	x	0%	43

Three patterns appeared in the gas CFL respondents' answers to the freeridership questions:

- 47 respondents (17%) had CFLs installed in their home before the home energy assessment, would have installed CFLs on their own within the next year, and would have installed the same number of CFLs that were received through the assessment. 8 of the 43 (17%) would have bought the CFLs at the same time and are being scored as 100 percent freeriders. 12 of the 47 (26%) would have bought the CFLs within three months and are being scored as 75 percent freeriders. 27 of the 47 (57%) would have bought the CFLs within a year and are being scored as 50 percent freeriders.
- 49 respondents (18%) had CFLs installed in their home before the home energy assessment and would have installed CFLs on their own within the next year, but would have installed fewer CFLs than what was provided during the home energy assessment and would have bought the additional CFLs within a year. These respondents are being scored as 12.5 percent freeriders.
- 112 respondents (40%) would not have installed any CFLs on their own within the next year and are being scored as zero percent freeriders.

Figure 2 shows a distribution of gas participant CFL survey respondents by the freeridership score assigned to each. Approximately 45 percent of CFL survey respondents indicated no freeridership. Additionally, 21 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for almost 34 percent of respondents.

Figure 2. Distribution of Gas Participant CFL Freeridership Scores



Air Sealing Freeridership Analysis

Table 12 shows the results of freeridership calculations for air sealing program participants that were surveyed. We discuss in-depth freeridership analysis for each participant stream in the following sections.

Table 12. Air Sealing Freeridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	203	0.05 (± 0.02)	0.07	0.03
Gas	80	0.11 (± 0.05)	0.16	0.06

Electric Participant Air Sealing Freeridership Results

Table 13 below shows the unique response combinations from the electric participant air sealing battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 13. Electric Participant Air Sealing Freeridership Results

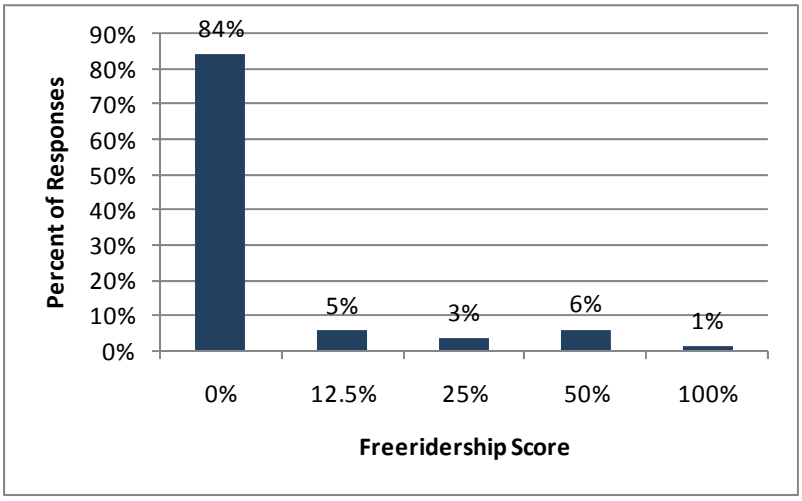
Before learning about the Mass Save program, were you already planning to <THER_SEAL?	Would you say it happened earlier than you had originally planned BECAUSE of the home energy assessment? That is, did you <THER_SEAL> earlier...	If the team hadn't done it, when do you think you would have done it? Would you have done it within six months, between six months and a year, or more than a year later than they did?	If the home energy assessment team had not done it, how likely would you have been to <THER_SEAL? Use a scale from 0-10, where 0 is "not at all likely" and 10 is "extremely likely".	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	2
Yes	Yes	Partial	Yes	50%	4
Yes	Yes	Partial	Partial	25%	1
Yes	Yes	Partial	No	0%	2
Yes	Yes	No	Partial	0%	2
Yes	No	Yes	Yes	50%	8
Yes	No	Yes	Partial	25%	1
Yes	No	Partial	Yes	25%	5
Yes	No	Partial	Partial	12.5%	3
Yes	No	Partial	No	0%	2
Yes	No	No	Yes	12.5%	1
Yes	No	No	Partial	0%	5
Yes	No	No	No	0%	3
Partial	x	x	No	0%	2
No	x	x	Yes	12.5%	7
No	x	x	Partial	0%	32
No	x	x	No	0%	123

Two patterns appeared in the electric air sealing respondents' answers to the freeridership questions:

- 123 respondents (60%) were not planning on air sealing before learning about the Home Energy Assessment program and were not likely to air seal if the home energy assessment team had not done it. These respondents are being scored as zero percent freeriders.
- In total, 32 respondents (16%) are receiving a freeridership score above zero percent, while 171 respondents (84%) are being scored as zero percent freeriders

Figure 3 shows a distribution of electric participant air sealing survey respondents by the freeridership score assigned to each. Approximately 84 percent of air sealing survey respondents indicated no freeridership. Additionally, 7 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for almost 9 percent of respondents.

Figure 3. Distribution of Electric Participant Air Sealing Freeridership Scores



Gas Participant Air Sealing Freeridership Results

Table 14 below shows the unique response combinations from the gas participant air sealing battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 14. Gas Participant Air Sealing Freeridership Results

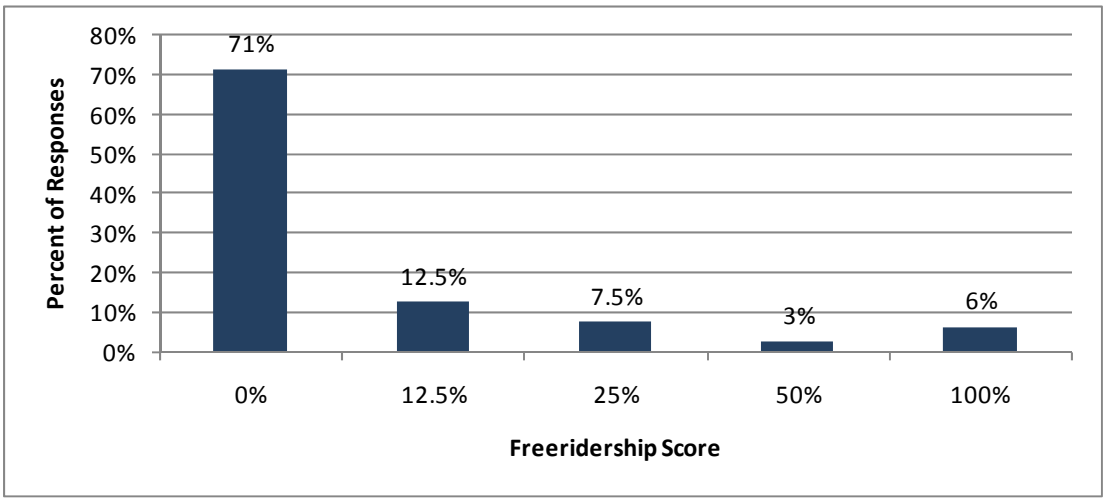
Before learning about the Mass Save program, were you already planning to <THER_SEAL?	Would you say it happened earlier than you had originally planned BECAUSE of the home energy assessment? That is, did you <THER_SEAL> earlier…	If the team hadn't done it, when do you think you would have done it? Would you have done it within six months, between six months and a year, or more than a year later than they did?	If the home energy assessment team had not done it, how likely would you have been to <THER_SEAL? Use a scale from 0-10, where 0 is "not at all likely" and 10 is "extremely likely".	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	5
Yes	Partial	Partial	Partial	25%	1
Yes	No	Yes	Yes	50%	1
Yes	No	Yes	Partial	25%	1
Yes	No	Yes	No	12.5%	1
Yes	No	Partial	Yes	25%	4
Yes	No	Partial	Partial	12.5%	3
Yes	No	No	Yes	12.5%	1
Yes	No	No	No	0%	1
No	x	x	Yes	12.5%	6
No	x	x	Partial	0%	8
No	x	x	No	0%	48

Two patterns appeared in the gas air sealing respondents' answers to the freeridership questions:

- 48 respondents (60%) were not planning on air sealing before learning about the Home Energy Assessment program and were not likely to air seal if the home energy assessment team had not done it. These respondents are being scored as zero percent freeriders.
- In total, 32 respondents (29%) are receiving a freeridership score above zero percent, while 171 respondents (71%) are being scored as zero percent freeriders.

Figure 4 shows a distribution of gas participant air sealing survey respondents by the freeridership score assigned to each. Approximately 71 percent of air sealing survey respondents indicated no freeridership. Additionally, almost 9 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for 20 percent of respondents.

Figure 4. Distribution of Gas Participant Air Sealing Freeridership Scores



Programmable Thermostat Freeridership Analysis

Table 15 shows the results of freeridership calculations for programmable thermostat program participants that were surveyed. We discuss in-depth freeridership analysis for each participant stream in the following sections.

Table 15. Programmable Thermostat Freeridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	84	0.10 (± 0.03)	0.13	0.07
Gas	29	0.16 (± 0.08)	0.24	0.08

Electric Participant Programmable Thermostat Freeridership Results

Table 16 below shows the unique response combinations from the electric participant programmable thermostat battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 16. Electric Participant Programmable Thermostat Freeridership Results

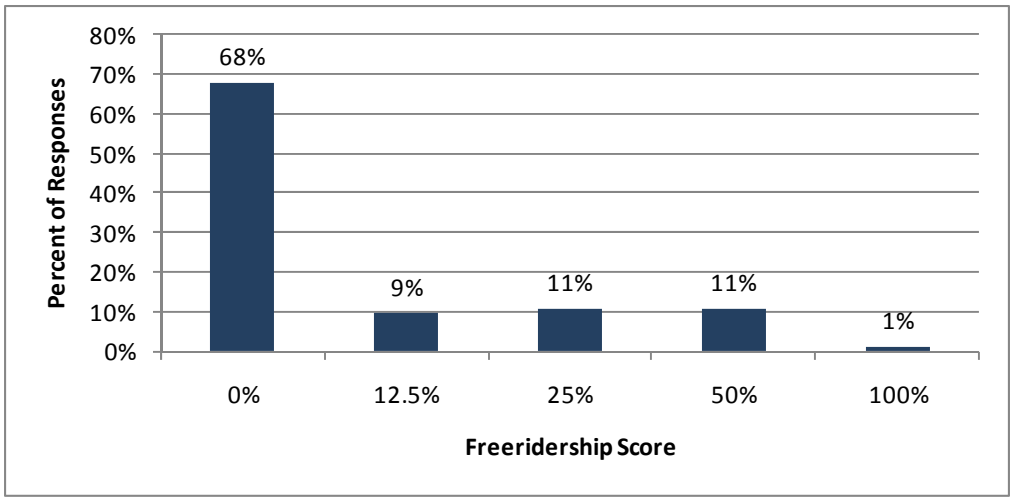
Before learning about the Mass Save program, were you already planning to <TSTAT>?	Would you say it happened earlier than you had originally planned BECAUSE of the home energy assessment? That is, did you <TSTAT> earlier…	If the team hadn't done it, when do you think you would have done it? Would you have done it within six months, between six months and a year, or more than a year later than they did?	If the home energy assessment team had not done it, how likely would you have been to <TSTAT? Use a scale from 0-10, where 0 is "not at all likely" and 10 is "extremely likely".	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	1
Yes	Yes	Partial	Partial	25%	2
Yes	No	Yes	Yes	50%	9
Yes	No	Yes	Partial	25%	1
Yes	No	Partial	Yes	25%	5
Yes	No	Partial	Partial	12.5%	4
Yes	No	Partial	No	0%	1
Yes	No	No	Yes	12.5%	2
Yes	No	No	Partial	0%	3
Yes	No	No	No	0%	1
Partial	x	x	Yes	25%	1
Partial	x	x	Partial	0%	1
No	x	x	Yes	12.5%	2
No	x	x	Partial	0%	10
No	x	x	No	0%	41

Two patterns appeared in the electric programmable thermostat respondents' answers to the freeridership questions:

- 41 respondents (49%) were not planning on installing a programmable thermostat before learning about the Home Energy Assessment program and were not likely to install a programmable thermostat if the home energy assessment team had not done it. These respondents are being scored as zero percent freeriders.
- In total, 27 respondents (32%) are receiving a freeridership score above zero percent, while 57 respondents (68%) are being scored as zero percent freeriders.

Figure 5 shows a distribution of electric participant programmable thermostat survey respondents by the freeridership score assigned to each. Approximately 68 percent of programmable thermostat survey respondents indicated no freeridership. Additionally, almost 12 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for about 20 percent of respondents.

Figure 5. Distribution of Electric Participant Programmable Thermostat Freeridership Scores



Gas Participant Programmable Thermostat Freeridership Results

Table 17 below shows the unique response combinations from the gas participant programmable thermostat battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 17. Gas Participant Programmable Thermostat Freeridership Results

Before learning about the Mass Save program, were you already planning to <TSTAT>?	Would you say it happened earlier than you had originally planned BECAUSE of the home energy assessment? That is, did you <TSTAT> earlier...	If the team hadn't done it, when do you think you would have done it? Would you have done it within six months, between six months and a year, or more than a year later than they did?	If the home energy assessment team had not done it, how likely would you have been to <TSTAT? Use a scale from 0-10, where 0 is "not at all likely" and 10 is "extremely likely".	Score	Number of Responses
Yes	Yes	Yes	Yes	100%	2
Yes	Partial	Partial	Partial	25%	1
Yes	No	Yes	Yes	50%	1
Yes	No	Yes	Partial	25%	1
Yes	No	Yes	No	12.5%	1
Yes	No	Partial	Yes	25%	4
Yes	No	Partial	Partial	12.5%	1
Yes	No	No	Yes	12.5%	2
Yes	No	No	No	0%	1
No	x	x	Yes	12.5%	1
No	x	x	Partial	0%	6
No	x	x	No	0%	8

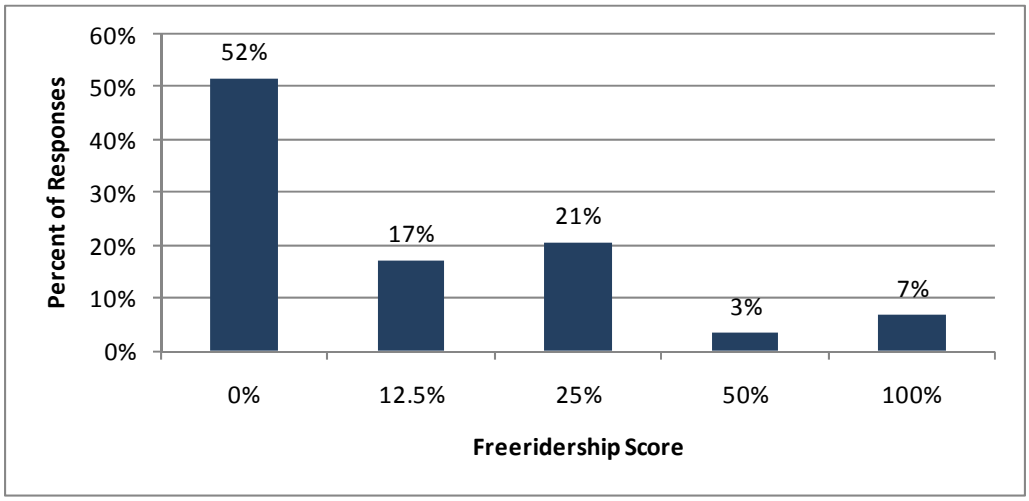
Two patterns appeared in the gas programmable thermostat respondents' answers to the freeridership questions:

- 8 respondents (49%) were not planning on installing a programmable thermostat before learning about the Home Energy Assessment program and were not likely to install a programmable thermostat if the home energy assessment team had not done it. These respondents are being scored as zero percent freeriders.

- In total, 14 respondents (48%) are receiving a freeridership score above zero percent, while 15 respondents (52%) are being scored as zero percent freeriders.

Figure 6 shows a distribution of gas participant programmable thermostat survey respondents by the freeridership score assigned to each. Approximately 52 percent of programmable thermostat survey respondents indicated no freeridership. Additionally, about 10 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for almost 38 percent of respondents.

Figure 6. Distribution of Gas Participant Programmable Thermostat Freeridership Scores



Insulation Freeridership Analysis

Table 18 shows the results of freeridership calculations for insulation program participants that were surveyed. We discuss in-depth freeridership analysis for each participant stream in the following sections.

Table 18. Insulation Freeridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	217	0.09 (± 0.02)	0.11	0.07
Gas	437	0.15 (± 0.02)	0.17	0.13

Electric Participant Insulation Freeridership Results

Table 19 below shows the unique response combinations from the electric participant insulation battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 19. Electric Participant Insulation Freeridership Results

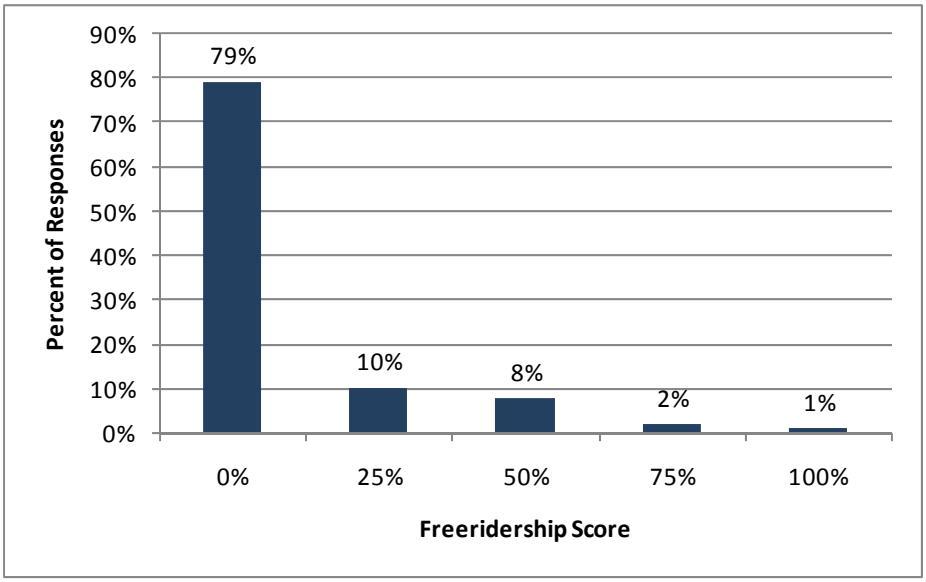
Before learning about the Mass Save program, were you already planning to buy (a) new <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Mass Save program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential".	Score	Number of Responses
Yes	Yes	Yes	100%	2
Yes	Yes	Partial	75%	4
Yes	Yes	No	50%	16
Yes	Partial	Partial	50%	1
Yes	Partial	No	25%	22
Yes	No	x	0%	29
No	x	x	0%	143

Three patterns appeared in the electric insulation respondents' answers to the freeridership questions:

- 143 respondents (66%) were not planning on buying insulation before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.
- 22 respondents (10%) were planning on purchasing insulation between six months and a year out before learning about the Home Energy Assessment program. These respondents reported that the Home Energy Assessment program rebate was influential in installing the high efficiency insulation and are receiving a decremented freeridership score of zero percent.
- In total, 45 respondents (21%) are receiving a freeridership score above zero percent, while 172 respondents (79%) are being scored as zero percent freeriders.

Figure 7 shows a distribution of electric participant insulation survey respondents by the freeridership score assigned to each. Approximately 79 percent of insulation survey respondents indicated no freeridership. Additionally, about 3 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for 18 percent of respondents.

Figure 7. Distribution of Electric Participant Insulation Freeridership Scores



Gas Participant Insulation Freeridership Results

Table 20 below shows the unique response combinations from the gas participant insulation battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 20. Gas Participant Insulation Freeridership Results

Before learning about the Mass Save program, were you already planning to buy (a) new <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Mass Save program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential".	Score	Number of Responses
Yes	Yes	Yes	100%	14
Yes	Yes	Partial	75%	17
Yes	Yes	No	50%	39
Yes	Partial	Yes	75%	7
Yes	Partial	Partial	50%	11
Yes	Partial	No	25%	42
Yes	No	x	0%	82
No	x	x	0%	225

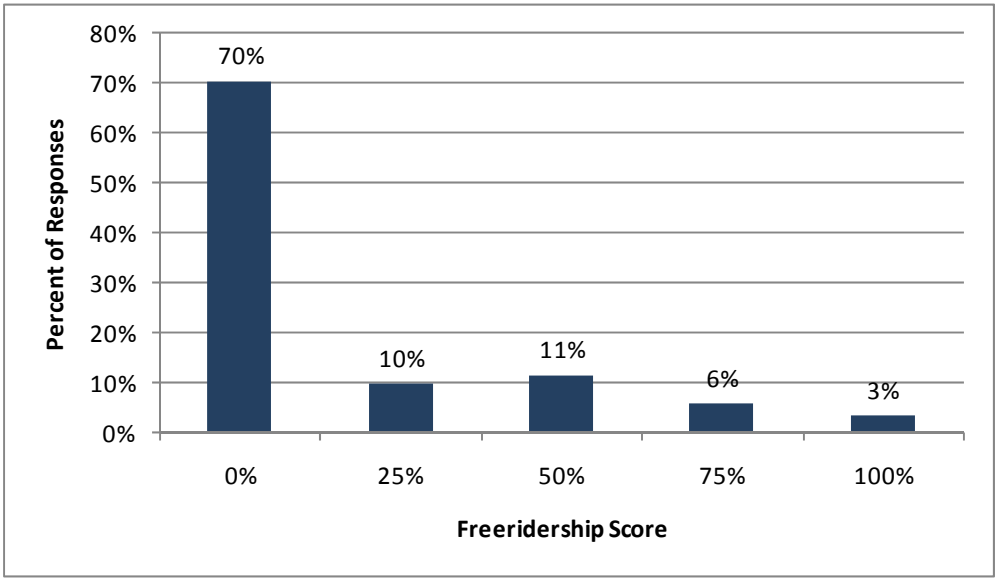
Four patterns appeared in the gas insulation respondents' answers to the freeridership questions:

- 225 respondents (51%) were not planning on buying insulation before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.

- 82 respondents (19%) would not have purchased the insulation within one year and are being scored as zero percent freeriders.
- 42 respondents (10%) were planning on purchasing insulation between six months and a year out before learning about the Home Energy Assessment program. These respondents reported that the Home Energy Assessment program rebate was influential in installing the high efficiency insulation and are receiving a decremented freeridership score of 25 percent.
- In total, 130 respondents (30%) of respondents are receiving a freeridership score above zero percent, while 307 respondents (70%) are being scored as zero percent freeriders.

Figure 8 shows a distribution of gas participant insulation survey respondents by the freeridership score assigned to each. Approximately 70 percent of insulation survey respondents indicated no freeridership. Additionally, about 20 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for 10 percent of respondents.

Figure 8. Distribution of Gas Participant Insulation Freeridership Scores



Electric Incented Measures Freeridership Analysis

Table 21 shows the results of freeridership calculations for electric incented measures program participants that were surveyed (excluding insulation participant, which are addressed above). We discuss in-depth freeridership analysis for each measure in the following sections.

Table 21. Electric Incented Measures Freeridership Results

Measure	Responses	FR Score	Upper Bound	Lower Bound
Heating System	141	0.26 (± 0.05)	0.31	0.21
Refrigerator	30	0.05 (± 0.05)	0.10	0.00
Water Heater	39	0.23 (± 0.10)	0.33	0.13

Electric Participant Heating System Freeridership Results

Table 22 below shows the unique response combinations from the electric participant insulation battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 22. Electric Participant Heating System Freeridership Results

Before learning about the Mass Save program, were you already planning to buy (a) new <MEASURE>?	Were you planning to purchase a <MEASURE> with the same level of energy efficiency before you learned about the Mass Save program?	Did you purchase the <MEASURE> earlier than you had originally planned because of the rebate you received through the MassSave program, or did the rebate not change the timing of when you purchased the <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Mass Save program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential".	Score	Number of Responses
Yes	Yes	Yes	Yes	Yes	100%	20
Yes	Yes	Yes	Yes	Partial	75%	7
Yes	Yes	Yes	Yes	No	50%	8
Yes	Yes	Yes	Partial	Yes	75%	2
Yes	Yes	Yes	Partial	No	25%	3
Yes	Yes	Yes	No	x	0%	2
Yes	Yes	No	Yes	Yes	50%	3
Yes	Yes	No	Yes	Partial	25%	3
Yes	Yes	No	Yes	No	12.5%	6
Yes	Yes	No	Partial	Yes	25%	1
Yes	Yes	No	Partial	No	0%	6
Yes	Yes	No	No	x	0%	11
Yes	Partial	Yes	Yes	Yes	75%	2
Yes	Partial	Yes	Yes	No	25%	2
Yes	Partial	Yes	Partial	No	12.5%	1
Yes	Partial	No	Partial	Partial	0%	1
Yes	Partial	No	Partial	No	0%	1
Yes	No	x	x	x	0%	24
No	x	x	x	x	0%	38

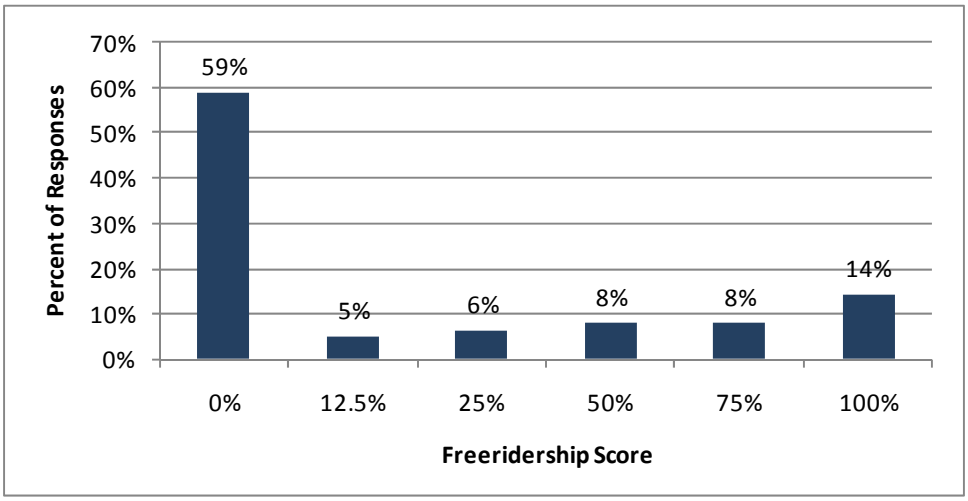
Four patterns appeared in the electric heating system respondents' answers to the freeridership questions:

- 38 respondents (27%) were not planning on buying a heating system before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.
- 24 respondents (17%) were not planning on purchasing a heating system with the same level of efficiency before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.
- 20 respondents' (14%) answers to the survey battery indicated freeridership for every question. These respondents are being scored as 100 percent freeriders.

- In total, 58 respondents (41%) are receiving a freeridership score above zero percent, while 83 respondents (59%) are being scored as zero percent freeriders.

Figure 9 shows a distribution of electric participant heating system survey respondents by the freeridership score assigned to each. Approximately 59 percent of heating system survey respondents indicated no freeridership. Additionally, almost 30 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for 11 percent of respondents.

Figure 9. Distribution of Electric Participant Heating System Freeridership Scores



Electric Participant Refrigerator Freeridership Results

Table 23 below shows the unique response combinations from the electric participant refrigerator battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 23. Electric Participant Refrigerator Freeridership Results

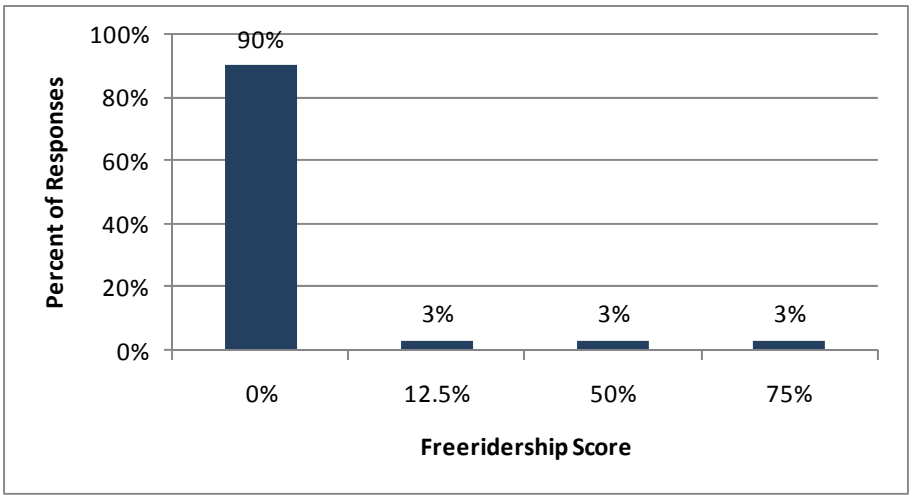
Before learning about the Mass Save program, were you already planning to buy (a) new <MEASURE>?	Were you planning to purchase a <MEASURE> with the same level of energy efficiency before you learned about the Mass Save program?	Did you purchase the <MEASURE> earlier than you had originally planned because of the rebate you received through the MassSave program, or did the rebate not change the timing of when you purchased the <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Mass Save program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential"	Score	Number of Responses
Yes	Yes	Yes	Yes	No	50%	1
Yes	Yes	No	Partial	Partial	12.5%	1
Yes	Yes	No	Partial	No	0%	1
Yes	Yes	No	No	x	0%	2
Yes	Partial	Yes	Yes	Yes	75%	1
Yes	No	x	x	x	0%	7
No	x	x	x	x	0%	17

Two patterns appeared in the electric refrigerator respondents' answers to the freeridership questions:

- 17 respondents (57%) were not planning on buying a refrigerator before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.
- In total, 3 respondents (10%) are receiving a freeridership score above zero percent, while 27 respondents (90%) are being scored as zero percent freeriders.

Figure 10 shows a distribution of electric participant refrigerator survey respondents by the freeridership score assigned to each. Approximately 90 percent of refrigerator survey respondents indicated no freeridership. Additionally, almost 7 percent of respondents were considered 50 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were observed for about 3 percent of respondents.

Figure 10. Distribution of Electric Participant Refrigerator Freeridership Scores



Electric Participant Water Heater Freeridership Results

Table 24 below shows the unique response combinations from the electric participant water heater battery, the freeridership score assigned to each combination, and the number of responses for each combination.

Table 24. Electric Participant Water Heater Freeridership Results

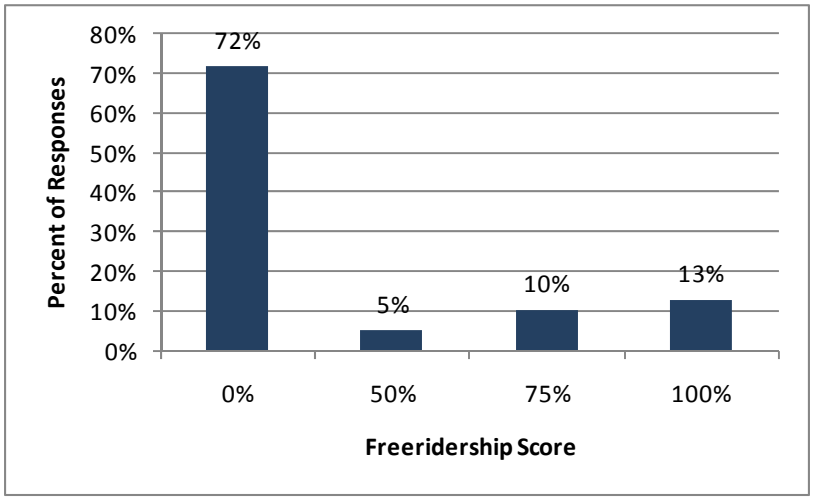
Before learning about the Mass Save program, were you already planning to buy (a) new <MEASURE>?	Were you planning to purchase a <MEASURE> with the same level of energy efficiency before you learned about the Mass Save program?	Did you purchase the <MEASURE> earlier than you had originally planned because of the rebate you received through the MassSave program, or did the rebate not change the timing of when you purchased the <MEASURE>?	If you had not received a rebate, when would you have purchased the <MEASURE>? Would you have purchased the <MEASURE> within six months, between six months and a year, or more than a year later than you did?	How influential was the Mass Save program rebate on your decision to install the high efficiency <MEASURE>? Use a scale from 0-10, where 0 is "not at all influential" and 10 is "extremely influential".	Score	Number of Responses
Yes	Yes	Yes	Yes	Yes	100%	5
Yes	Yes	Yes	Yes	Partial	75%	3
Yes	Yes	Yes	Yes	No	50%	1
Yes	Yes	Yes	Partial	Yes	75%	1
Yes	Yes	Yes	Partial	Partial	50%	1
Yes	Yes	No	Partial	No	0%	1
Yes	Yes	No	No	x	0%	4
Yes	No	x	x	x	0%	5
No	x	x	x	x	0%	18

Three patterns appeared in the electric water heater respondents' answers to the freeridership questions:

- 18 respondents (46%) were not planning on buying a water heater before learning about the Home Energy Assessment program and are being scored as zero percent freeriders.
- 5 respondents' (13%) answers to the survey battery indicated freeridership for every question. These respondents are being scored as 100 percent freeriders.
- In total, 11 respondents (28%) are receiving a freeridership score above zero percent, while 28 respondents (72%) are being scored as zero percent freeriders.

Figure 11 shows a distribution of electric participant refrigerator survey respondents by the freeridership score assigned to each. Approximately 72 percent of water heater survey respondents indicated no freeridership. Additionally, almost 7 percent of respondents were considered 28 percent freeriders or higher, while low levels of freeridership (12.5% and 25%) were not observed for any respondents.

Figure 11. Distribution of Electric Participant Water Heater Freeridership Scores



Spillover Analysis

This section presents a detailed analysis of additional energy-efficient measures customers installed after participating in the Home Energy Assessment program. As mentioned in the spillover methodology section, due to the uncertainty of the efficiency and type of measure, self-report participant spillover was estimated only for CFL and insulation measures using gas participant survey data. The evaluation team determined that spillover information obtained from the gas participant surveys was only detailed enough for CFL and insulation measures to accurately estimate spillover.

Spillover Results

Table 25 shows the results of freeridership calculations for CFL and insulation program participants that were surveyed. We discuss in-depth freeridership analysis for each measure in the following sections.

Table 25. CFL and Insulation Participant Spillover Results

Measure	Spillover Rate	Upper Bound	Lower Bound
CFL	0.19 (± 0.05)	0.24	0.14
Insulation	0.08 (± 0.02)	0.10	0.06

Participant CFL Spillover Results

Table 26 below shows the number of CFLs that were installed in the past year outside the Home Energy Assessment program for gas program participants that were surveyed. If a respondent answered 5, 6, or 7 for the influence of the Home Energy Assessment program on their additional CFL purchases, half of the additional CFL purchases are attributed to the program. In total, 244 CFLs that survey respondents installed outside the program are attributable to the Home Energy Assessment program.

Table 26. CFL Spillover Responses

Respondent Type by Influence of Home Energy Assessment on CFL Purchases	Respondents that Reported Installing Additional CFLs Outside the Program	Purchased CFLs After Participating in Home Energy Assessment Program	Sum of # of CFLs Installed in the Past Year
8,9, or 10 for Influence	32	30	135
5,6, or 7 for Influence	28	28	109
Total	60	58	244

Table 27 below shows the two inputs for calculating the number of CFLs per surveyed participant. The total number of spillover CFLs installed in the past year (244) taken from Table 24 above is divided by the total number of surveyed participants (435) to arrive at the number of spillover CFLs per surveyed participant (0.56).

Table 27. Number of CFLs per Surveyed Participant

# of Spillover CFLs Installed in Past Year	244
Total # of Surveyed Participants	435
Spillover CFLs per Surveyed Participant	0.56

Table 28 below shows inputs for calculating the estimated number of CFLs delivered by the program for the participant survey sample. The variables "Percent of Customers Receiving CFLs" and "Bulbs per Customer Receiving CFLs" contained in Table 26 are values generated from information contained in the electric and gas program tracking databases provided by the PAs.

Table 28. Estimated Number of Bulbs Delivered

Percent of Customers Receiving CFLs	0.47
Bulbs per Customer Receiving CFLs	6.16
Total # of Surveyed Participants	435
Estimated # of CFLs Delivered By The Program	1265

Table 29 below shows the inputs for calculating the average number of CFLs received by surveyed program participants. This average includes Home Energy Assessment participants that did not report receiving CFLs. The "Average CFLs Per Participant" in Table 27 below is calculated by dividing the "Estimated # of CFLs Delivered by the Program," calculated in Table 26, by the "Total # of Surveyed Participants."

Table 29. Average CFLs Per Surveyed Participant

Estimated # of CFLs Delivered By The Program	1265
Total # of Surveyed Participants	435
Average CFLs Per Participant (including those that did not receive them)	2.91

Table 30 below shows the inputs for calculating the CFL spillover rate for surveyed program participants. The variable "Spillover CFLs per Surveyed Respondent" calculated in Table 25 is

divided by the variable "Average CFLs Per Participant" calculated in Table 27 to arrive at the "CFL Participant Spillover Rate" of 0.19.

Table 30. CFL Participant Spillover Rate

Spillover CFLs per Surveyed Respondent	0.56
Average CFLs Per Participant (including those that did not receive them)	2.91
CFL Participant Spillover Rate	0.19

Participant Insulation Spillover Results

Table 31 below shows the number of surveyed participants who installed insulation in the past year outside the Home Energy Assessment program. If a respondent answered 5, 6, or 7 for the influence of the Home Energy Assessment on their additional insulation purchase, half of the additional insulation purchase was attributed to the program. In total, 25 insulation installations that survey respondents performed outside the program are attributable to the Home Energy Assessment program.

Table 31. Insulation Spillover Purchases

Respondent Type by Influence of Home Energy Assessment Program on Insulation Purchases	Respondents that Reported Purchasing Additional Insulation Outside the Program	Purchased Insulation After Participating in Home Energy Assessment Program
8,9, or 10 for Influence	23	23
5,6, or 7 for Influence	4	2
Total	27	25

Table 32 below shows the inputs for calculating the insulation spillover rate for surveyed program participants. The variable "Purchased Insulation After Participating in Home Energy Assessment Program" calculated in Table 29 is divided by the variable "Surveyed Participants That Installed Insulation Through The Program" to arrive at the insulation spillover rate of 0.08, which is represented by the spillover insulation purchases by surveyed participants expressed as a percentage of surveyed participants who installed insulation through the program.

Table 32. Insulation Participant Spillover Rate

Purchased Insulation After Participating in Home Energy Assessment Program	25
Surveyed Participants That Installed Insulation Through The Program	329
Spillover Insulation Purchases by Surveyed Participants Expressed As A Percentage of Surveyed Participants Who Installed Insulation Through The Program	0.08

Participant Self-Report Freeridership Logic Models

Diagram 3 (CFLs), Diagram 4 (Air Leak Sealing and Programmable Thermostats), Diagram 5 (Insulation), and Diagram 6 (Heating Systems, Water Heaters and Refrigerators – RCS Only) show logic models the evaluation team developed for assessing freeridership in the Home

Energy Assessment program for electric and gas participants. The list below matches program measures to the specific logic model.

All possible combinations of these responses to the survey questions were assigned a freeridership score. The evaluation team assigned scores by 1/8 and 1/4 increments (12.5 percent, 25 percent, 50 percent, 75 percent, and 100 percent). A survey respondent receiving a score of 100 percent would be a 100-percent freerider. Likewise, a score of 0 percent would indicate the respondent was not a freerider. Scores between 0 percent and 100 percent would indicate respondents were partial freeriders.

In the diagrams below, a respondent may not persist through the full logic model. For example, in the incented measures survey appearing in Diagram 5, respondents who answered “No” to the first freeridership question were not asked the remaining questions as they were automatically assigned 0 percent freeridership.

Diagram 3. CFL Direct Install Freeridership Logic Model

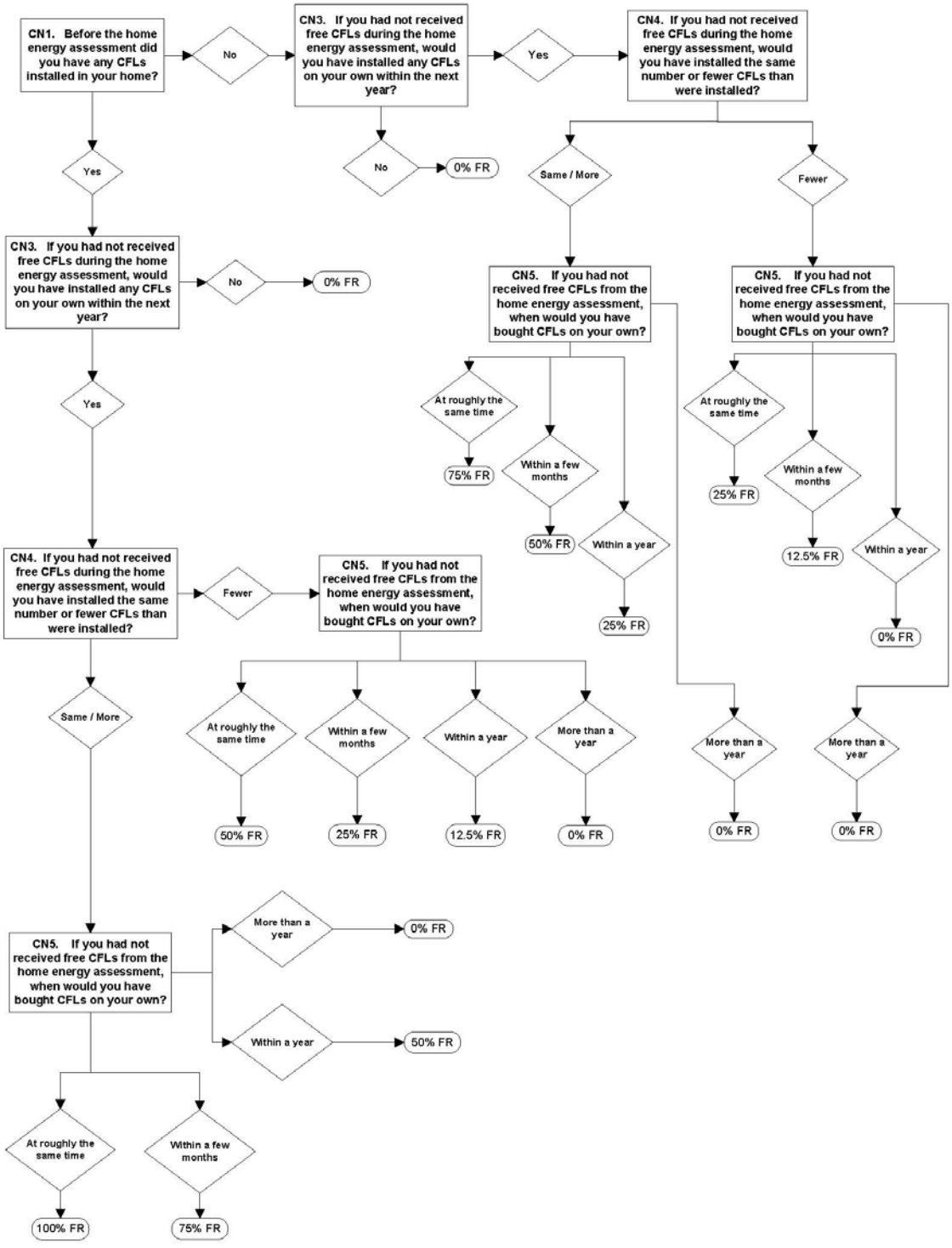


Diagram 4. Direct Install Freeridership Logic Model

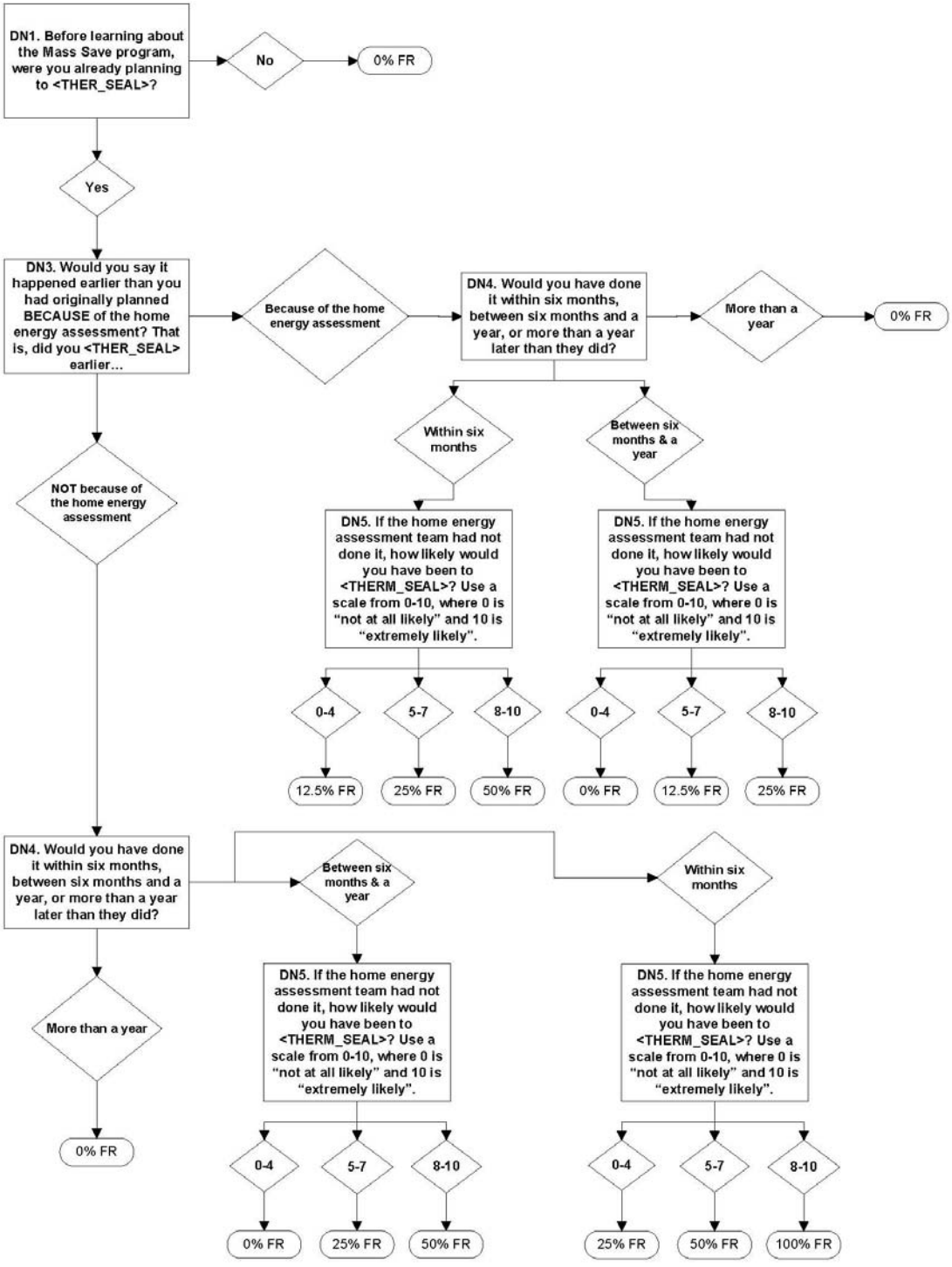


Diagram 5. Incented Insulation Measures Freeridership Logic Model

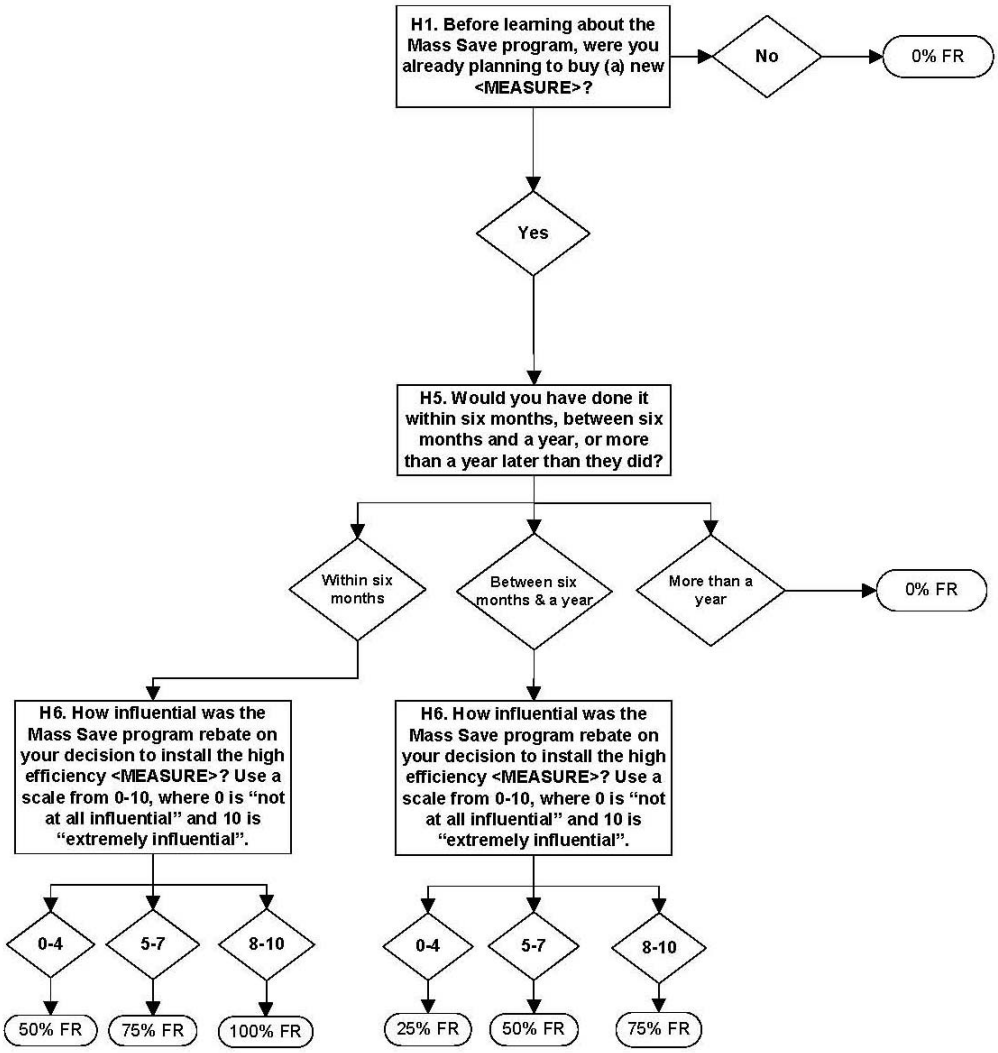
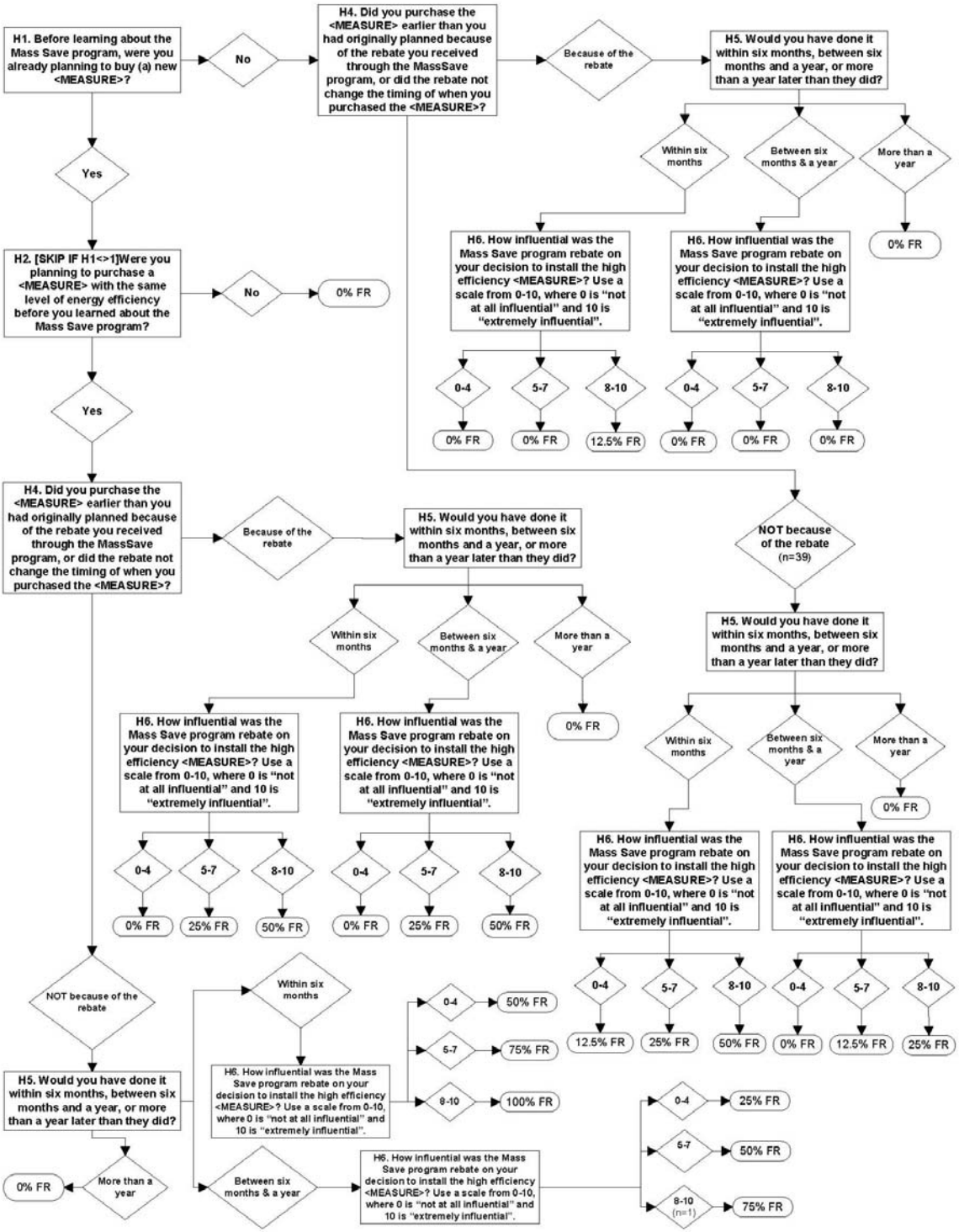


Diagram 6. Incented Other Measures Freeridership Logic Model



4. Discrete Choice Modeling

This study used discrete choice modeling to derive freeridership and nonparticipant spillover estimates for insulation and duct-sealing measures installed under the Gas Weatherization program. Models were estimated for thermostats and are presented here, but the results were not used in the final composite NTG estimates due to extremely high NPS estimates.

This family of models is widely employed in a variety of market research settings when seeking to determine how various factors influence consumer behavior. The present application used a mixed logit model to evaluate Home Energy Assessment's marketing and incentive programs' impact on consumer decisions regarding energy-efficiency investments.

Discrete choice models assume individuals base their decisions on a desire to maximize personal utility functions. Broadly interpreted, a utility function may consider not only direct financial interests, but also more idiosyncratic concerns, such as aesthetics or conservation ethics. To account for such a wide variety of factors, each individual's utility function, with respect to a given set of choices—$j = 1, 2, \ldots, J$—is composed of two distinct parts,

$$U(j) = V(j) + \epsilon(j).$$

The first part, $V(j)$, represents the portion of the individual's utility, as known to the researcher, in that it is a function of traits the researcher has observed. For instance, insulation, (j), is represented as a function of:

- Age
- Family size
- Home ownership (1 if customer owned the home, 0 otherwise)
- Audit (1 if customer received an audit, 0 otherwise)
- Dollar value of insulation incentives
- Program awareness

As the second component of the individual's utility, $\epsilon(j)$, is considered the portion researchers cannot account for, it is modeled as random. The different types of discrete choice models can largely be distinguished by their different assumptions regarding the joint distribution of $\epsilon(j)$.

For a given specification of explanatory variables believed to influence a customer's decision, the function's parameters are fitted to a dataset via maximum likelihood or a similar method. Based on the fitted parameters, a researcher can estimate the probability of an individual's choosing one option or another as a function of his or her explanatory variables.

Our model considered three alternatives each customer (either a participant or nonparticipant) faced when deciding whether or not to purchase insulation or duct-sealing measures. As noted, the mixed logit model estimates the probability of an individual choosing one of the three alternatives illustrated for insulation measures in Figure 12 and for programmable thermostats in Figure 13.

Figure 12. Discrete Choice Model Alternatives – Insulation Measures

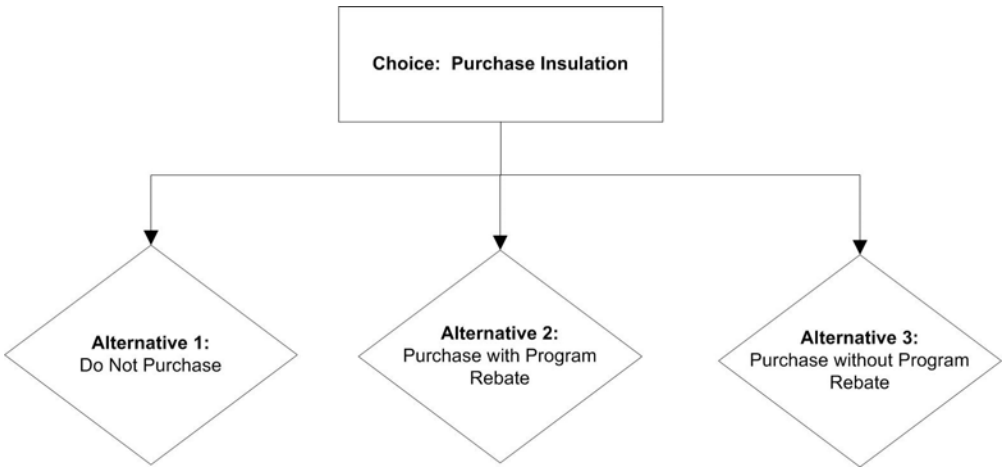
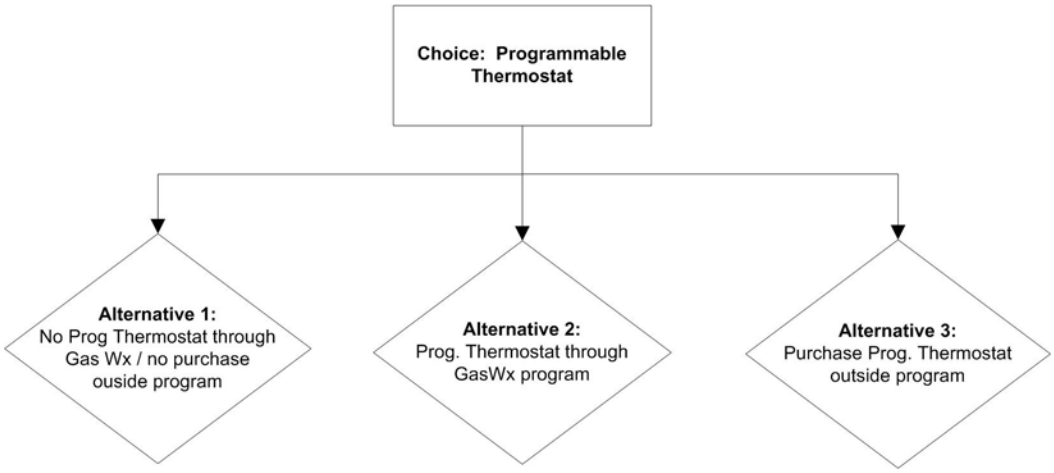


Figure 13. Discrete Choice Model Alternatives – Programmable Thermostat



Data

The evaluatin team used the following data to inform the discrete choice model:

- **Survey Data**. The evaluation team conducted separate surveys of Gas Weatherization participants and nonparticipants throughout Massachusetts. Participants received either a home energy assessment, installed an insulation or duct-sealing measure rebated through the program, or both. In all, we drew upon data from 836 completed surveys, including 435 Gas Weatherization participants and 401 nonparticipants. We removed 17 of the 401 respondents from the nonparticipant survey data because they stated that they lived in high rise multifamily buildings, and thus would not be eligible for the Gas Weatherization program. Our final analysis is based on 819 completed surveys, 435 participants and 384 non participants. All surveys obtained demographic, attitudinal, program awareness, purchase information, and self-reported assessments of the program's impact on individual decisions.
- **Program Tracking Data.** Cadmus assembled program tracking data from the six Massachusetts natural gas providers (NGrid, NStar, Berkshire, Columbia, NEG, and

Unitil). These data were used to obtain insulation quantity, cost, incentive, and energy savings for each participant.

As summarized in Table 33, we created several additional variables, drawn from raw survey and program tracking data specifically used in the discrete choice analyses.

Table 33. Modeling Variables Created from Survey and Program Tracking Data

Name	Description
Age	Age of survey respondent
Audit	Presence of Home Energy Assessment (1=yes, 0=no)
Incentive	Incentive Amount
Own	Respondent owns home (1=yes, 0=no)
FamilySize3	Family size of 3 or more persons (1=yes, 0=no)
Awareness	Respondent is aware of Home Energy Assessment program (1=yes, 0=no)
NonPart	Respondent is a Gas Weatherization program participant (1=yes, 0=no)
Alt2	Alternative 2-specific constant (1=Alternative 2, 0=otherwise)
Alt3	Alternative 3-specific constant (1=Alternative 3, 0=otherwise)
Audit x Alt2	Interaction of Audit and Alternative 2 constant
Incentive x Alt2	Interaction of Incentive and Alternative 2 constant
Own x NonPart x Alt3	Interaction of Own, NonPart, and Alternative 3 constant
FamilySize3 x Alt3	Interaction of FamilySize3 and Alternative 3 constant
Awareness x Alt3	Interaction of Awareness and Alternative 3 constant

Note: See Figure 12 for definitions of Alternative 2 and Alternative 3

We interacted several of the variables with specific alternatives to ensure identifiability of coefficients in the utility function, and because impacts of a given variable on an individual's utility function could vary across alternatives. For example, assume there is some variable which, for each fixed individual, takes the same value for all three choice alternatives. This variable's effect on decision-making cannot be captured by a discrete choice model as its impact on utility is the same for each option, while the *differences* among alternative utilities drive decisions.

In developing the final dataset used for modeling, we made three additional considerations:

1. We weighted each individual used in the development of the mixed logit model to correct for nonparticipant sample bias. Survey results showed that relative to the general population, the nonparticipant sample underrepresented young people, renters, and those with less education. Because these personal characteristics were likely to be associated with the behaviors and attitudes influencing program participation, our nonparticipant survey weights were based on these three characteristics. As participant survey responses were considered representative of the Gas Weatherization program population, we assumed all responses had equal weight.

2. The SAS implementation of the mixed logit model (Proc MDC) does not accept direct sample weights, we used respondent replication to account for the described nonparticipant survey weights. For example, a respondent with a survey weight of three would have his or her response repeated three times in the final modeling data. Table 34 and

3. Table **35** summarize the number of respondents used in the final modeling dataset, grouped by the alternative each respondent actually selected.
4. As the participant sample naturally skewed toward insulation purchasers relative to the population at large, we used choice-based sampling to balance the sum of survey weights between (the alternative under which the respondents made a purchase). Under this approach, we randomly selected respondents who chose the inside program purchase alternative (Alternative 2), such that the sum of survey weights was comparable to the group choosing the outside program purchase alternative, as illustrated in the insulation model and in
5. Table **35** for the programmable thermostat model.

Table 34. Number of Respondents and Weighting in Final Modeling Data by Chosen Alternative – Insulation and Duct Sealing

Alternative	Chosen Alternative	N	Sum of Weights
1	No Purchase	372	1355
2	Purchase through GasWx program	228	228
3	Purchase outside GasWx program	60	229

Table 35. Number of Respondents and Weighting in Final Modeling Data by Chosen Alternative – Programmable Thermostats

Alternative	Chosen Alternative	N	Sum of Weights
1	No Purchase	659	2618
2	Purchase through GasWx program	56	224
3	Purchase outside GasWx program	59	223

Results – Insulation and Duct Sealing

Our freeridership and nonparticipant spillover estimation process began by fitting a mixed logit model with the discrete choice alternatives described in Figure 12 and customer utility variables chosen from Table 33. To determine the explanatory variables used in the final model, we compared several alternative model specifications in terms of the observed sample probability or the alternative share, versus the average of the models' probabilities across all customers, and coefficient signs and statistical significance. Mixed logit models do not lend themselves well to finding an absolute measure of model fit (e.g., the r-squared term in an ordinary least-squares regression). However, as shown in Table 36, the estimated probabilities for each alternative were close to those observed in our modeling sample.

Table 36. Observed and Modeled Probabilities by Alternative

Alternative	Observed Sample Probability	Modeled Probability
No Purchase	75%	71%
Purchase through GasWx program	13%	16%
Purchase outside GasWx program	13%	13%

The fitted model's mean coefficient estimates follow in Table 37. We used these parameters to estimate the knowable portion of each respondent's utility for each alternative, which in turn was translated into a probability of selecting each alternative. As such, the nominal values of the parameters in a discrete choice model not easily interpreted. However, the sign of the parameter estimates provide useful information. For example, the sign on the Audit x Alt2 parameter in

Table **37** is positive, meaning a home energy assessment increases the modeled probability that a respondent would choose to purchase insulation through the Gas Weatherization program.

Table 37. Final Model Parameter Estimates

Model Term	Parameter Estimate	t Value
Age	-0.068	-22.36
Audit x Alt2	1.791	6.52
Incentive x Alt2	0.002	13.25
Own x NonPart x Alt3	1.978	11.89
FamilySize3 x Alt3	-0.729	-5.28
Awareness x Alt3	0.384	2.75

Observation weighting increases the apparent significance of the estimated coefficients in the final model by replicating observations. However, we ran an equivalent model (same model terms as shown above) on an unweighted sample and noted that the signs of the coefficients were identical, that all variables remained significant, and that the magnitudes of the coefficients themselves were within one standard error of those shown in Table 37.

After we fit the final model described above, we set up two hypothetical scenarios to estimate impacts of freeridership and nonparticipant spillover:

- **Scenario 2: No program impact scenario.** Under this scenario, we determined freeridership impacts by estimating what modeled probabilities would look like absent program impacts. That is, we estimated probabilities using the parameter estimates shown in
- Table **37** with the home energy assessment, incentives, and program awareness removed from the set of explanatory variables as shown in Table 38.
- **Scenario 3: No nonparticipant awareness scenario.** Under this scenario, we determined nonparticipant spillover impacts by estimating what the modeled probabilities would look like absent program awareness. That is, we estimated probabilities using the parameter estimates shown in
- Table **37** with program awareness removed from the set of explanatory variables as shown in Table 38.

Table 38. Model Terms used in Hypothetical Scenarios

Model Term	Scenario 1 Fitted Model	Scenario 2 No Program Impact	Scenario 3 No Nonparticipant Awareness
Age	X	X	X
Audit x Alt2	X		X
Incentive x Alt2	X		X
Own x NonPart x Alt3	X	X	X
FamilySize3 x Alt3	X	X	X
Awareness x Alt3	X		

Note: X denotes model term is included in explanatory variable set

Table 39. Modeled Probabilities from Observed Model and Hypothetical Scenarios

Alternative	Scenario 1 Modeled Probability	Scenario 2 No Program	Scenario 3 No Nonparticipant Awareness
No Purchase	71%	83%	73%
Purchase through GasWx program	16%	5%	16%
Purchase outside GasWx program	13%	11%	11%

Table 39 shows results from the hypothetical scenarios. The direction of movement in the modeled probabilities follows intuition, in that the inside-program purchase probability decreases without incentives or the Home Energy Assessment program, and the outside-program purchase probability decreases absent awareness. However, the results shown in Table 39 are applicable to the survey samples used to estimate the model, but are not indicative of the actual number of insulation and duct sealing installations in the state of Massachusetts, either inside or outside of the Gas Weatherization program. Thus, our freeridership and spillover estimates cannot be derived from the model results shown in Table 39 without controlling for the actual sizes of the participant and nonparticipant populations.

Population approximations are shown in Table 40. Program tracking data indicated that the Gas Weatherization program approved approximately 10,000 participants over a two-year period (2009–2010), the period over which we asked non-participants about their energy-efficiency purchases and installations. Approximately 500,000 homes in the nonparticipant population are eligible for the Gas Weatherization program. Thus, the population's total size was approximately 510,000 homes. We then applied survey results and the estimated participant and nonparticipant population sizes noted above to estimate population proportions for each of the three purchase alternatives in the overall population (Table 40). These population proportions drive the estimates of freeridership and nonparticipant spillover.

Table 40. Population Adjusted Proportions by Model Alternative

Alternative	Participants (N=10,000)	Non-Participants (N=500,000)	Population Adjusted Model Probability for Scenario 1
No Purchase	21.4%	85.1%	83.8%
Purchase through GasWx program	78.6%	0.0%	1.5%
Purchase outside GasWx program	0.0%	14.9%	14.6%

Note: Participant and nonparticipant shares are determined through survey questions

We then used the hypothetical probabilities for Scenarios 2 and 3 relative to Scenario 1 (Table 39) and the population adjustments (Table 40) to obtain the population adjusted results for Scenarios 2 and 3 shown in Table 41. The population adjusted probabilities for these scenarios are calculated as

$$p_{sa} = \frac{q_a K_{sa}}{\sum_{j=1}^{3} q_j K_{sj}}$$

where p_{sa} is the estimated population proportion for alternative a (a=1,2,3) under scenario s (s=2,3), q_a is the population proportion for alternative a under scenario 1, and K_{sa} is the ratio of the modeled probability for alternative a under scenario s to the modeled probability for alternative a under scenario 1.

Table 41. Population Adjusted Proportions from Final Model and Hypothetical Scenarios

Alternative	Scenario 1 Population Adjusted Model Probability	Scenario 2 Population Adjusted No Program Impact	Scenario 3 Population Adjusted No Nonparticipant Awareness
No Purchase	83.8%	88.1%	86.0%
Purchase through GasWx program	1.5%	0.4%	1.6%
Purchase outside GasWx program	14.6%	11.4%	12.4%

We estimated freeridership by looking at the proportion of the population that would have chosen the inside-program purchase alternative under Scenario 2 relative to Scenario 1. From Table 41, we estimated a 29% freeridership rate by taking the ratio of the inside-program purchase proportion to that of the no-program impact scenario (0.4% / 1.5% = 29%). That is, we estimated that 29% of the actual program insulation and duct sealing installations would have taken place had participants not received incentives or a home energy assessment.

We estimated nonparticipant spillover in two steps. The first step is to calculate the difference in the proportion of the outside-program purchase alternative between Scenario 1 and Scenario 3 in Table 41 (14.6% - 12.4% = 2.2%). This rate suggests that awareness of the Home Energy Assessment program drives 2.2% of the eligible population to purchase insulation or duct sealing measures outside of the program over the course of two years. However, we noted that 52% of nonparticipant respondents claiming to be aware of the Home Energy Assessment program at the time of the survey were not aware of the program when purchasing insulation or duct sealing (Table 42). Thus, in our second step, we adjusted the final nonparticipant spillover rate from

2.2% down to 1.1% (2.2% x 52% = 1.1%), to account for the lack of program awareness at the time of purchase. We rounded this estimate to an even 1% to estimate nonparticipant spillover.

Table 42. Reasons for not Applying for Rebate through Home Energy Assessment Program - Nonparticipant Insulation or Duct Sealing Installs

Reason	N	Percent
Was not aware of Home Energy Assessment program at time of installation	21	52%
Was not aware program offered cash incentives	14	34%
Did not want to submit rebate	1	3%
Was not consulted (i.e. contractor installed or already installed)	1	3%
Other	3	7%
Total	40	100%

Note: N is weighted with nonparticipant sample weights

The 1% nonparticipant spillover rate was relative to the overall population (510,000 homes), thus accounting for approximately 5,100 insulation or duct-sealing installations. Expressed in terms of participant population size (10,000), the nonparticipant spillover rate became 51%, which we rounded to 50% in the composite NTG analyses.

Table 43. FR and NPS Summary - Insulation and Duct Sealing

Metric	Percentage of Gross Savings
Free Ridership	30%
Nonparticipant Spillover	50%

Non-Participant Spillover Uncertainty

There are many sources of uncertainty in the estimation of NPS, both quantifiable and not quantifiable. The uncertainty falls into two broad categories, uncertainty around size of the Gas Weatherization program's non-participant population and discrete choice model uncertainty.

The critical driver of uncertainty in the NPS estimate is the size of the non-participant population, which we estimated to be 500,000. We derived this estimate using data from the United States Census Bureau's American Community Survey (ACS) and the Massachusetts Residential Appliance Saturation Survey (RASS) conducted in 2009 to derive the non-participant population size.

Table 44. Non-Participant Population Size Assumptions

Source	Characteristic	% of Homes	90% Conf Interval (+/-)
ACS	Single Family Home	79%	0.1%
ACS	Gas Heating Fuel	47%	0.1%
ACS	Not Low Income	90%	0.1%
ACS	Pre-1990 Construction	87%	0.1%
RASS	< R19 Attic Insulation	67%	6.7%

Note: No insulation precision explicitly stated in RASS, assuming +/- 10% relative precision

After multiplying the number of single family homes in Massachusetts (2.7 million) through by the factors in Table 44, we get approximately 500,000 homes. Combining the confidence bands

in Table 44, we obtain a 90% confidence interval for the estimate of approximately of +/- 7 percent, or 35,000 homes. This confidence interval encapsulates the sample variance for the secondary data sources used in the approximation.

However, Cadmus did not receive detailed audit data or collect any on-site data on the amount of insulation as part of the 2010 evaluation, and thus do not have reliable information on the proportion of homes that actually qualify for the Gas Weatherization program other than the estimate above. Consequently a confidence interval based on sampling error from secondary data sources does not fully capture the uncertainty in our estimate of the non-participant population size. Subsequent evaluations of the RCS and Gas Weatherization programs will involve a detailed assessment of available audit data and, if necessary, on-site data collection that will be able to determine a proportion of program eligible homes more reliably and thus will be able to give a better estimate of the size of the non-participant population.

In addition to uncertainty around the size of the non-participant population, there is some uncertainty around the model coefficients shown in Table 37. In particular, the Awareness x Alt3 coefficient drives the estimate of NPS. A 90% confidence interval for the Awareness x Alt3 coefficient in Table 37 is (0.155, 0.613), which translates into modeled shares of the Purchase outside GasWx program alternative under Scenario 1 in Table 39 of 12 percent and 14 percent. We obtain a 90% confidence interval for NPS of +/- 5 percent (e.g., NPS of 45 to 55%) when converting the 12 percent to 14 percent into population shares, and then into NPS when only considering uncertainty around the modeled program awareness coefficient. A complete NPS confidence interval capturing the joint uncertainty around all estimated model coefficients would require a more complicated bootstrapping procedure but would still be subject to the inexact estimate of population size described above.

Results – Programmable Thermostats

Our freeridership and nonparticipant spillover estimation process for programmable thermostats began by fitting a mixed logit model with the discrete choice alternatives described in Figure 13 and customer utility variables chosen from Table 33. To determine the explanatory variables used in the final model, we compared several alternative model specifications in terms of the observed sample probability or the alternative share, versus the average of the models' probabilities across all customers, and coefficient signs and statistical significance. Table 45 shows the estimated probabilities for each alternative against those observed in our modeling sample.

Table 45. Observed and Modeled Probabilities by Alternative

Alternative	Observed Sample Probability	Modeled Probability
No Thermostat	75%	71%
Thermostat through GasWx program	13%	16%
Purchase Thermostat outside GasWx program	13%	13%

The fitted model's mean coefficient estimates follow in Table 46. As with the insulation model, we used these parameters to estimate the knowable portion of each respondent's utility for each alternative, which in turn were translated into a probability of selecting each alternative.

Table 46. Final Model Parameter Estimates – Programmable Thermostat Model

Model Term	Parameter Estimate	t Value
Age	-0.077	-23.80
Audit x Alt2	2.060	11.29
Own x NonPart x Alt3	1.906	10.96
Awareness x Alt3	0.796	5.51

Similar to the insulation model described above, we set up two hypothetical scenarios to estimate impacts of freeridership and nonparticipant spillover:

- **Scenario 2: No program impact scenario.** Under this scenario, we determined freeridership impacts by estimating what modeled probabilities would look like absent program impacts. That is, we estimated probabilities using the parameter estimates shown in Table 46 with the Home Energy Assessment and program awareness removed from the set of explanatory variables as shown in Table 47.
- **Scenario 3: No nonparticipant awareness scenario.** Under this scenario, we determined nonparticipant spillover impacts by estimating what the modeled probabilities would look like absent program awareness. That is, we estimated probabilities using the parameter estimates shown in Table 46 with program awareness removed from the set of explanatory variables as shown in Table 47.

Table 47. Model Terms used in Hypothetical Scenarios

Model Term	Scenario 1 Fitted Model	Scenario 2 No Program Impact	Scenario 3 No Nonparticipant Awareness
Age	X	X	X
Audit x Alt2	X		X
Own x NonPart x Alt3	X	X	X
Awareness x Alt3	X		

Note: X denotes model term is included in explanatory variable set

Table 48, Table 49, and Table 50 apply the eligible population adjustment methodology described previously to thermostats. We estimated that approximately 325,000 homes in the nonparticipant population qualify for the program and do not already have a programmable thermostat.

Table 48. Modeled Probabilities from Observed Model and Hypothetical Scenarios

Alternative	Scenario 1 Modeled Probability	Scenario 2 No Program	Scenario 3 No Nonparticipant Awareness
No Thermostat	82%	88%	84%
Thermostat through GasWx program	9%	3%	9%
Purchase Thermostat outside GasWx program	9%	9%	6%

Table 49. Population Adjusted Proportions by Model Alternative

Alternative	Participants (N=10,000)	Non-Participants (N=325,000)	Population Adjusted Model Probability
No Thermostat	87.1%	83.3%	83.4%
Thermostat through GasWx program	12.9%	0.0%	0.4%
Purchase Thermostat outside GasWx program	0.0%	16.7%	16.2%

Note: Participant and nonparticipant shares are determined through survey questions

Table 50. Population Adjusted Proportions from Final Model and Hypothetical Scenarios

Alternative	Scenario 1 Population Adjusted Model Probability	Scenario 2 Population Adjusted No Program Impact	Scenario 3 Population Adjusted No Nonparticipant Awareness
No Thermostat	83.4%	84.2%	87.4%
Thermostat through Gas Wx program	0.4%	0.1%	0.4%
Purchase Thermostat outside Gas Wx program	16.2%	15.7%	12.2%

Note: Percentages are rounded to nearest tenth

Thermostat discrete-choice based FR and NPS estimates are shown Table 51. As with insulation, the timing of awareness required a downward adjustment to spillover. Only 38% of nonparticipant respondents claimed to be aware of the Home Energy Assessment program at the time of the survey were aware of the program when they purchased their programmable thermostat (Table 52). Thus, the 4% rate from the difference in the proportion for the outside-program purchase alternative between scenario 1 and scenario 3 in Table 50 (16.2% - 12.2% = 4.0%) must be reduced. However, even this reduction to 1% yields a total of 3,300 NPS thermostats which overwhelms raw program participants by a magnitude of 3 or a 300% spillover rate. The estimate is clearly too high to be credible and is likely an artifact of the eligible population figure. We therefore do not use the discrete choice results for FR, NPS, and NTG in 2010. We plan to revisit this issue for the 2011 program as the DSM potential study will provide a much better estimate of the number of homes eligible for programmable thermostats.

Table 51. Discrete Choice Net-to-Gross Summary – Programmable Thermostats

Metric	Percentage of Gross Savings
Free Ridership	30%
Nonparticipant Spillover	300%

Note: These results are not used in the final composite NTG estimates.

Table 52. Reasons for not Applying for Rebate through the Home Energy Assessment Program – Programmable Thermostats

Reason	N	Percent
Was not aware of Home Energy Assessment program at the time of purchase	40	62%
Installed by myself/friend/relative	14	21%
Was not aware program offered programmable thermostats	3	4%
Contractor installed it without consultation	2	4%
Savings wasn't worth it	1	2%
Other	4	7%
Total	65	100%

Note: N is weighted with nonparticipant sample weights

5. Home Improvement Contractor Interviews

Overview

The evaluation team fielded a telephone survey with a total of 33 home improvement (insulation) contractors. Survey responses formulated a picture of how contractors viewed the Home Energy Assessment program, revealed participation barriers, and provided an important viewpoint into the program's potential market effects on the home improvement market.

The survey instrument contained modules and questions directed specifically either at participants or nonparticipants. Contractors were considered active in the program if they received an incentive for any of their residential retrofit weatherization projects in the last two years, inactive if they were listed as a participating contractor on the PA Webpage, but had not received an incentive in the last two years, and nonparticipating if they did not participate in the program at all. Only contractors installing insulation were targeted to complete the survey.

Participating contractor questions explored the following research areas:

- Program influence on changes in business practices
- Program influence on changes in market
- Program attributable nonparticipant spillover impacts
- Satisfaction with the program[4]
- Awareness and potential of HEAT Loan Program

Nonparticipating contractor questions explored the following issues:

- Business practices
- Program attributable nonparticipant spillover impacts
- Awareness of the program
- Awareness and potential of HEAT Loan
- Participation barriers

We chose to leverage the sample frame and survey effort by incorporating both participant and nonparticipant questionnaires into one. This approach allowed contractors who may have participated in the past or were not identified from PA lists to respond to the survey instrument as participants.

Contractor Survey Sample

The sample was drawn from two primary sources. First, a list of participating contractors was compiled from five separate lists of participating "Insulation Contractors" listed on MassSave.com. Currently, the site lists participating contractors operating in National Grid, NSTAR, Columbia Gas, Cape Light Compact, and Berkshire Gas service territories.[5] When the

[4] Process-oriented research topics will be explored in a later evaluation report.

[5] Lists of participating contractors for New England Gas and Unitil currently do not appear on MassSave.com (May 23, 2011).

sample was prepared, 211 records were listed across the five combined PAs. As duplicates across PAs occurred (contractors can service more than one gas territory), we removed duplicates, resulting in 110 *unique* contractor contacts to include in the sample frame. Table 53 shows the distribution of the participant sample frame across the five PA contractor lists. The sample was randomly selected from this list, so distribution of completed surveys would represent a cross-section of contractors serving all the PAs.

Table 53. Participating Contractors by PA

PA*	Total Participating Weatherization Contractors	Percent of Participant Sample Frame
National Grid	77	70%
NSTAR	73	66%
Cape Light Compact	9	8%
Columbia Gas	32	29%
Berkshire Gas	20	18%
Total	110*	

*The sum and percentages by PA sum up to more than the total because contractors can serve more than one utility. In total, there were 110 unique contacts from the participant lists on MassSave.com.

Once the participant list was prepared, we drew a nonparticipant sample from a purchased list from Survey Sampling Inc. To choose a list that would guarantee we reached home improvement contractors for whom the program would apply, we compared the participant sample frame to five different Standard Industrial Classification (SIC) code contact lists, which seemed most likely to fit the industry about which we sought to learn. We chose the purchased list corresponding to an SIC code with which the participant sample most overlapped (by phone number or business name). Of 110 participants, 23 appeared on the purchased list of the 111 contractors we chose. The nonparticipant sample frame, therefore, resulted in a list of 88 unique home improvement contractors.

Table 54 shows the final sample frame, which included 198 contacts, over half of which (56 percent) were included on the MassSave.com participant lists. Surveys were completed by 31 participants and two nonparticipants. Two participant-respondents had not been listed on MassSave.com, but had participated in the program, so for analysis, they were treated as inactive participants.

Table 54. Survey Completions and Sample Frame by Participation Status

Respondent Type	Total Sample Frame	Percent of Sample Frame	Completed Surveys	Percent of Total Surveyed
Participant	110	56%	31*	94%
Nonparticipant	88	44%	2	6%
Total	198		33	

* Two participants treated as participants based on their survey responses had not been included on the participant list. Seven participants were treated as inactive participants, meaning their insulation projects in the past two years had not received an incentive from the program; however, they had received an incentive from the program.

As clearly a greater percent of surveys were completed by those from the participant list, we examined the dispositions by sample frame. Table 55 compares call dispositions between the two sample frames. Among both sample frames, the greatest barrier to interviewing respondents was an inability to get in touch with an individual. As expected, the nonparticipant sample frame had

much higher incidences of nonworking numbers or those less inclined to have the time or interest to respond to the survey. Less than 10 percent of the nonparticipant sample frame did not install insulation or did not install insulation in residences. All sample pieces were used (meaning, all numbers were dialed), and all numbers indicating a potential were dialed eight or more times.[6]

While we could not definitely determine the majority of insulation contractors participated in the program, the nonparticipant list having so many non-working and unanswered numbers (we achieved only two completions) appeared to indicate the majority of residential retrofit insulation contractors in Massachusetts were likely listed as participants on the PA Web pages.

Table 55. Call Disposition by Sample Frame

Disposition	Participant Sample Frame		Nonparticipant Sample Frame	
	Total Contacts	Percent of Sample Frame	Total Contacts	Percent of Sample Frame
Unable to Reach (no answer)	49	45%	30	34%
Interviewed	29	26%	4*	5%
Phone number issue	6	5%	25	28%
Call back	17	15%	9	15%
Refusal	8	7%	13	15%
Do not install insulation	1	1%	5	6%
Commercial contractor only	0	0%	2	2%
Total	110		88	

*The two participants treated as participants based on their survey responses were treated as nonparticipants as we analyzed the barriers to interviewing those from the nonparticipant sample frame.

† "Call back" includes those where we were able to connect with an individual who was willing to speak with us; however, we were asked to call back in order to conduct or complete the interview. In all cases, these individuals were attempted as many times as possible until the overall quota was met.

NPS Methodology

To examine the possibility of nonparticipant spillover, we followed a three-step process. First, we examined the total number of homes that the contractors weatherized, quantifying the number of homes outside the program that might qualify as nonparticipant spillover. Second, we asked respondents to assess the program importance on their business practices, and ultimately if the program might have influenced these non-program projects. Finally, we summed up the number of non-program homes that were impacted by participation in the program and divided by the total number of program homes to estimate the nonparticipant spillover percentage.

Number of Program vs. Non-Program Homes Weatherized

As explained in the methodology, participating contractors were split into two groups: active participants and inactive participants. Inactive participants are those who have had some affiliation with the program (e.g., training and incentives) at some point, but none of their projects have received an incentive in the past two years. Interviews were conducted with seven inactive participants and 24 active participants. Nonparticipants are those respondents who have never received any training or incentives from the program. Because we were only able to interview two nonparticipants, we provide little quantitative analysis for these respondents.

[6] Any number not resulting in a refusal, a complete, a non-working number, and still considered in the correct business category was dialed until it was considered "exhausted" or until the total quota for completes was met.

In total, participating contractors report they have performed retrofit weatherization projects in 11,034 homes in the last two years (Table 56). Based on the 29 contractors that could provide information on the number of residential retrofit weatherization projects they completed, the average contractor performed a total of 377 projects in the last two years, or about 189 projects/year. Among the active participants, approximately 46 percent of their projects had received incentives.

When the active participants were asked why the over 5,400 homes that were weatherized outside the program did not receive an incentive, the most common response (seven of the 22 respondents) was that the projects were ineligible because the homes were heated by oil, another fuel, or another utility. Two of the active contractors stated they didn't file for incentives for many homes because the rebates take too long, one respondent mentioned they weren't conducting safety tests, and one reported that they weren't certified. Responses included:

> *"It was a different fuel source, oil heated homes."*
>
> *"Depending on the utility, their heat source, or they didn't have an audit done prior."*
>
> *"Because they were oil customers. They didn't have natural gas."*
>
> *"If I can get away with it, I try not to sell the rebate. The rebate is a turn off because it takes too long to get an audit. It adds a lot of paper work to the customer. If the customer can just be a cash customer, it can be easier and better to go without a rebate."*
>
> *"Some people don't want to wait for the rebate. They want the work done now."*
>
> *"[I am] not yet certified to do the rebate and customers did not want to wait 3 months to do it."*
>
> *"Some people have sewer systems, moisture issues, combustion safety test didn't pass."*

All of these non-program homes were considered candidates for nonparticipant spillover. Respondents that reported that the customer received rebates, or the home was low income or receiving fuel assistance were disqualified for nonparticipant spillover with the assumption they might have received incentives under other programs.

The inactive participants were far less familiar with the program and often had a difficult time explaining why they didn't apply for incentives. Most of the inactive participants, therefore, were disqualified for any nonparticipant spillover potential.

Table 56. Incented Retrofit Weatherization Projects in Last Two Years

Participant Type	Total Estimated Homes Weatherized	Estimated Homes Receiving Incentives	Estimated Homes Not Receiving Incentives
Active (n=22)	10,045 (100%)	4,639 (46%)	5,406 (54%)
Inactive (n=7)	889 (100%)	0 (0%)	889 (100%)
Total (n=29)*	10,934 (100%)	4,639 (42%)	6,295 (58%)

*Two contractors were unable to provide information regarding the number of total homes or the number of homes receiving incentives.

Program Importance

As a second step in examining nonparticipant spillover, the survey asked respondents to report the program importance in their work, and in particular on the non-program projects.

Forty percent of participating contractors reported that the program has caused their company to begin using new product or practices that increase energy efficiency.[7] At least six respondents mention that they have taken up performing air sealing or now more comprehensively perform this service as a result of the program. Others mention that they now use spray foam or other diagnostic tools they had not used before like infrared scans and blower door tests. Responses included:

> *"[We now] do more thorough air sealing application. [We now perform] more tests that we didn't do before."*
>
> *"[We now use] two-part foam insulation, touch and seal. [We use the] product shown in the boot-camp program, high performance duct-mastic, and cellulous."*
>
> *"[We use] insulation covers for recessed lighting."*

Fifty-two percent of participating contractors report the program has caused their company to more heavily market the importance of energy efficiency to their customers.[8] Respondents who say the program has caused their company to more heavily market the importance of energy efficiency to their customers were asked to rate the importance of the program on these changes using a scale of 0 to 10, where 0 is "not at all important" and 10 is "extremely important." They provide a mean rating of 7.5 for the program's importance on this increase in marketing. For our analytical purposes, we consider a rating of 7 or higher a valuable level of importance.

As a third measure of program importance, participating contractors were asked to rate the program in its importance *overall* for projects that do not receive an incentive.[9] Seven of the 22 active participants reported an influence of "7" or higher, while three inactive participants reported a "7" or higher.

Respondents reporting the program as important (rating it a 7 or higher) were asked how the program was important in weatherization projects they performed without receiving rebates. Respondents reported they started taking a "whole building" approach, used new diagnostics (e.g., program rules), used spray foam, or conducted more air sealing. Responses included:

> *"We took a whole building approach. [We have been] following the standards in the Mass Save [Home Energy Assessment] book."*
>
> *"We used the same rules."*

---

[7] Survey question BP10: As a result of your experiences with the Mass Save program, has your company begun using new products or practices that greatly increase energy efficiency [IF <INACTIVE>=0, READ] of the projects that do not receive rebates from the Mass Save program?

[8] Survey question BP12: Has your involvement with the Mass Save program caused your company to more heavily market the importance of energy efficiency to your customers?

[9] Survey question BP 6: There are a number of ways Home Energy Assessment could have influenced your professional practices. How important would you say your experiences with the Home Energy Assessment program have been on the weatherization projects your company completed that did not receive rebates from the program? Please use a scale where 0 is "not at all important" and 10 is "extremely important."

"[We use a] better air sealing methodology."

To put the program in context with other factors, we asked respondents about the relative importance of factors on the weatherization projects that did not receive incentives from the program.[10] Respondents provided a mean rating of 5.5 for the importance of other factors (n=15), a value slightly higher than that attributed to the program. Important factors they cited included: other training they received, experience in the field, and overall increases in demand.

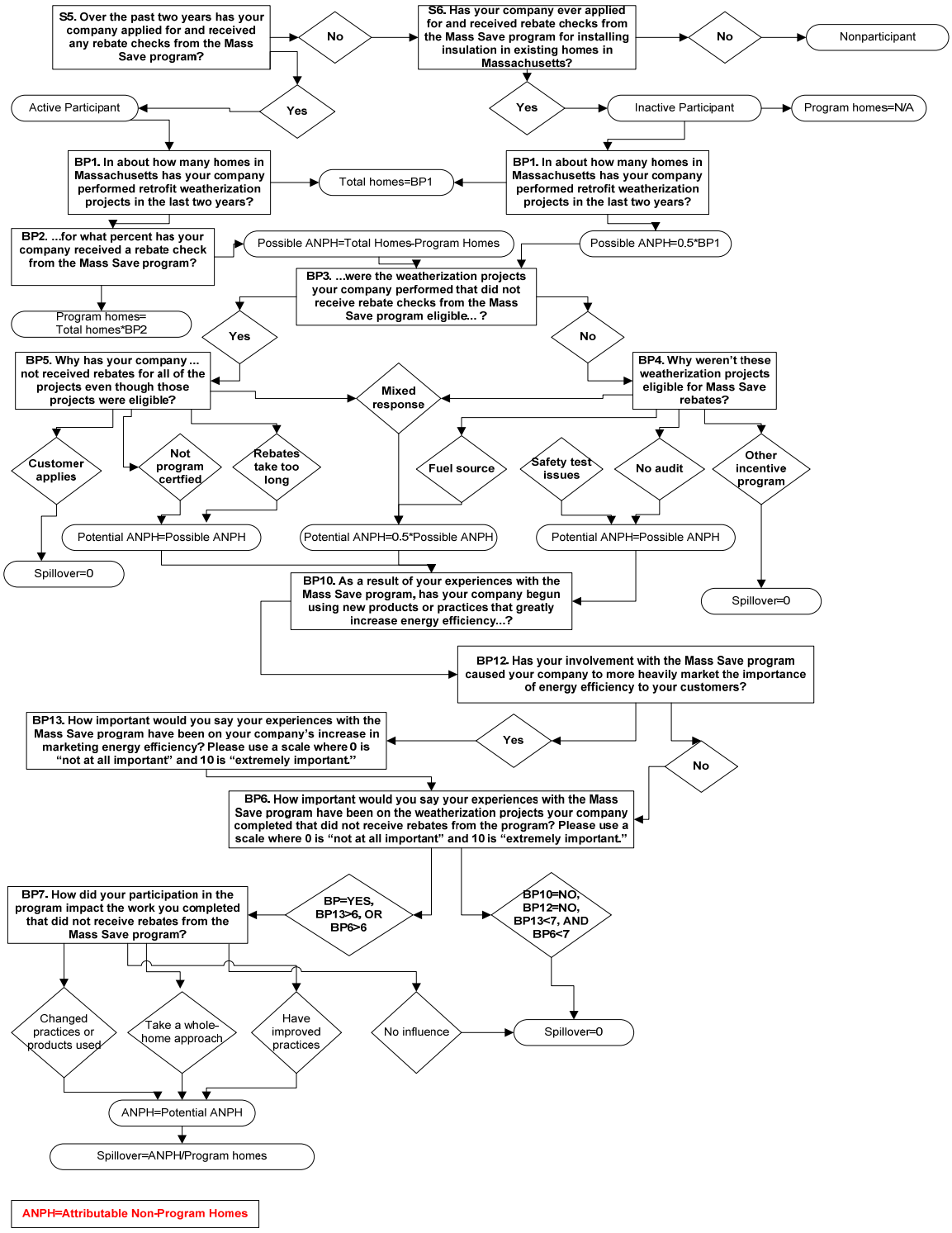
Finally, these three measures of program influence on non-program projects were combined into a single construct. Respondents reporting the program impacted their products/practices, their marketing of energy efficiency, or their overall non-program projects were assigned candidates for potential nonparticipant spillover. In total, 15 of 22 active participants and four inactive contractors met these criteria.

Nonparticipant Spillover Algorithm

Diagram 4, below, presents the detailed algorithm that was used to determine nonparticipant spillover from the home insulation contractors. The key parameter for the spillover calculation is the Attributable Non-Program Homes (ANHP) – those homes where contractors performed weatherization upgrades but did not receive program incentives.

[10] Survey question BP7a: How important would you say other factors not related to the program have been on the weatherization projects your company completed that did not receive rebates from the Home Energy Assessment program? (IF NEEDED: Please use the same scale where 0 is "not at all important" and 10 is "extremely important.")

Figure 14. Contractor Spillover Logic Model



Quantifying Nonparticipant Spillover

To quantify nonparticipant spillover, we combined the results for the number of eligible, non-program homes with the program's importance for these homes. For each respondent, numbers of program-influenced, non-program homes were determined. As shown in Table 57, a total of 3,555 non-program homes (out of 6,295 non-program homes) were determined to be influenced by the program. In total, this represented nonparticipant spillover of 76 percent.[11]

Table 57. Quantifying Nonparticipant Spillover

Participant Type	Total Estimated Program Homes Weatherized (A)	Estimated Homes not Receiving Incentives (B)	Number of Nonparticipant Spillover Home Qualified (C)	Nonparticipant Spillover Percentage (C/A)
Active (n=22)	4,639	5,406	3,314	71%
Inactive (n=7)		889	241	5%
Total (n=29)*	4,639	6,295	3,555	76%

[11] Note we also asked respondents to compare the energy savings in non-program homes to program homes. Although a number of respondents reported that the savings were greater, we assumed no additional savings in non-program homes (i.e., the savings in each non-program home is equivalent to a program home) because the customer survey did not demonstrate any additional spending for non-program vs. program projects.

6. NTG Findings

Final participant freeridership (FR), participant spillover (PS), nonparticipant spillover (NPS), and net-to-gross (NTG) values are composite estimates (rather than a simple average) of the various research methods employed. The estimates were developed using a triangulation process, incorporating our experience, professional judgment, and understanding of the programs.

Table 58 summarizes the applicable methodologies available by measure and NTG component for the 2010 Home Energy Assessment (RCS and Gas Weatherization) program.

Table 58. 2010 RCS and Gas Weatherization NTG Component Estimation by Measure

Measure Category	Measure	Participant Freeridership	Participant Spillover	Nonparticipant Spillover
CFL Direct Installs	CFL	CSR	CSR	NA
Direct Installs	Air Leak Sealing	CSR	NA	NA
	Programmable Thermostat	CSR	NA	NA
Incented Measures	Heating System	CSR	NA	NA
	Insulation	CSR, DC	CSR	DC, ICSR
	Refrigerator	CSR	NA	NA
	Water Heater	CSR	NA	NA
CSR: Customer Self Report				
DC: Discrete Choice				
ICSR: Insulation Contractor Self Report				
NA: Not Available				

Additional information relating to the composite estimates is provided in the discussion below.

- **FR Estimation for Identical Electric and Gas Program Measures**. Although FR was estimated by measure separately for RCS and Gas Weatherization, findings were aggregated when measure-specific findings were determined to be not statistically different across the survey samples. Combining the estimates made sense intuitively, as FR (as an example, for CFLs), would not logically differ based on whether participants had gas heat (Gas Weatherization) or any other type of heating system (RCS). Electric and gas savings weights were derived from the PA's 2011 Benefit Cost Ratio (BCR) model, which contains the most recent estimates of measure-specific overall savings for RCS and Gas Weatherization.

- **Insulation FR Estimation**. For insulation, the composite FR estimate of 20% was based on the average of the customer self-report (10%) and the discrete choice FR analyses (29%). Although discrete choice models were also estimated for thermostats in 2010 resulting in good model fits and statistically significant parameters, the application of the results to NTG analyses required a good estimate of the population of customers who do not currently have programmable clock thermostats. This information is not available at this time, but should become available through the 2011 Home Energy Assessment program evaluation and will be revisited in the future. Additionally, we anticipate that further refinements to the survey instruments and samples in 2011 will facilitate the application of the discrete choice model to other electric and gas measures.

- **PS Estimation**. The 2010 RCS survey had a very general, non-measure specific PS question battery. In the 2011 Gas Weatherization survey program, participants were asked about several specific types of measures they might have installed on their own, including two major measures in terms of Gas Weatherization savings: CFLs and insulation. These PS estimates were applied to electric CFL and insulation participants, respectively. No other measures received PS credit for the 2010 Home Energy Assessment program.

  While refrigerator, heating system, and water heating system measures were part of the Gas Weatherization participant question battery, they cannot be used to calculated spillover because participants obtaining incentives for these measures don't exist, per se, for the Gas Weatherization program. There is no denominator of participants to use in a PS calculation. We anticipate extending these questions to the 2011 RCS survey in order to expand the PS components in the 2011 evaluation.

- **NPS Estimation**. NPS is estimated only for insulation. The NPS estimate of 50% determined through the discrete choice analysis was used as the final, composite estimate. Although the contractor self-reports show NPS at approximately 75%, we chose to be more conservative given that these NPS estimates are somewhat high. No other measures received NPS values for the 2010 Home Energy Assessment program.

Results

Table 59 presents NTG findings, by measure and overall, for the 2010 Home Energy Assessment Program.

Table 59. 2010 RCS and Gas Weatherization NTG Findings

Measure Category	Measure	Participant Freeridership	Participant Spillover	Nonparticipant Spillover	NTG
CFL Direct Installs	CFL	22% ± 2%	19% ± 5%	0%	97%
Direct Installs	Air Leak Sealing	7% ± 3%	0%	0%	93%
	Programmable Thermostat	11% ± 5%	0%	0%	89%
Incented Measures	Heating System	28% ± 5%	0%	0%	72%
	Insulation	20%*	8% ± 2%	50% ± 5%	138%
	Refrigerator	5% ± 5%	0%	0%	95%
	Water Heater	25% ± 10%	0%	0%	75%
Overall		18%	7%	23%	112%

Note: Insulation FR is not shown – it is a composite of customer self-report and discrete choice methods

It is critical to interpret the results presented below correctly. With this intention, the evaluation team offers the following four caveats.

1. As noted above, uncertainly exists regarding all estimates of NTG. While the evaluation team has provided the most accurate point estimate of NTG possible given available information, it is important to recognize that the choice of methods and their implementation is somewhat subjective, resulting in uncertainty as to the "true" NTG

values.[12]

Let's consider insulation, where we estimate an NTG of 138%. If, however, we use the insulation contractor NPS results instead of the discrete choice model estimates, NPS would be 75% instead of 50%, raising the NTG to 163%. Conversely, it is also possible that the insulation NTG estimate is high. A recent meta-evaluation conducted by a colleague collected NTG estimates from other studies and found an average of 63% for insulation for similar programs.[13] It is not clear whether participant spillover, let alone nonparticipant spillover was factored into these evaluation findings. The wide variance in the estimates—perhaps as much as ± 50% across all measures in the program—is why some jurisdictions assume that freeridership and spillover cancel out and use an NTG value of 100% to evaluate program cost-effectiveness.

2. The NTG values determined through this effort are applicable to the RCS and Gas Weatherization programs in Massachusetts. For example, one should not use these estimates for the Low Income or Multifamily programs given the very real differences in market actors and energy-efficiency decision making in the segments targeted by those programs.

3. As the RCS and Gas Weatherization programs' designs change, and the energy-efficiency knowledge and practices of market actors evolve, we expect the NTG results to change too. For example, in 2010 some of the PAs were still providing insulation incentives without an audit, but that practice has been terminated. Additionally, we anticipate that the 2011 or 2012 evaluations will attempt to estimate PS and NPS estimates for measures where they were not available from the 2010 evaluation.

4. The overall NTG of 112% is a weighted average of the measure-specific NTG values listed in Table 3 based on the distribution of installed measures statewide in 2010. The overall NTG will differ for each PA based on their specific distribution of installed measures in 2010. Likewise, any application of the NTG estimates for planning purposes should consider the implication of changes in program design or measure distribution over time.

[12] This uncertainty is very different—and much larger—than the confidence or error bounds for estimated parameters within a given approach. For example, we report the sample-size based error bounds for the self-reported freeridership estimates in Chapter 3, but these are quite small relative to the methodology and scoring choices made by energy-efficiency professionals.

[13] *Home Energy Performance Electric Program Evaluation—PY2* , Prepared for Ameren Illinois by The Cadmus Group Inc. / Energy Services, March 2011.

Appendix A: Sampling and Weighting

Participant Surveys

RCS Sampling

Generally, the RCS participant sample was stratified by program participation. As a result, National Grid and NSTAR represent the majority of the sample. However, to ensure adequate representation for Unitil and WMECO, the Cadmus team implemented a minimum target of 70 completes per utility. Since Unitil only had 16 completes for 2010 when the sample was developed, a census was attempted for the utility.

Participant records in the program participation tracking databases with missing contact information (i.e., telephone number or name) or missing participation data (i.e., measure installed) were excluded from the sample. Each PA's database had some incomplete information requiring the removal of participants from the sample. In general, the larger PAs provided cleaner and more complete databases. Overall, about one-quarter of all participants were removed from the sample due to incomplete information.

After removing all participants with missing information, we created a final sample. Since the survey took place before the end of 2010, the data received from PAs covered different portions of the year. To annualize the participation counts for stratification and address the disparity in data delivery dates, we compared the number of participants in the sample by PA to the last participation date for each PA. This allowed us to estimate the number of customers likely to have participated in the program in 2010 overall (see Table 60 below).

Table 60. 2010 RCS - Sample Extrapolation

PA	Date of Last Participation	2010 Days Represented	Percent of 2010 Represented	Extrapolation Factor
Cape Light	June 30, 2010	179	49.7%	2.01
National Grid	July 31, 2010	210	58.3%	1.71
NSTAR	August 16, 2010	225	62.5%	1.60
Unitil	October 16, 2010	285	79.2%	1.26
WMECO	September 16, 2010	255	70.8%	1.41

After applying the extrapolation factor to the partial 2010 datasets, we calculated an initial survey target for each PA by taking the proportion of the total number of extrapolated 2010 participants for each PA and multiplying it by the target survey population (1,200). We then adjusted these numbers to satisfy a minimum sample size for each PA of 70 participants or, in cases where this was not possible, a census of participants served as the survey target. The final sample design can be seen in Table 61.

Table 61. 2010 RCS - Sampling Design

PA	Actual 2010 Participants Provided	Extrapolated 2010 Participation	Percent of 2010 Extrapolated Participants	Survey Target (Unadjusted)	Survey Target (Adjusted)	Percent of Total Surveys (Adjusted)
Cape Light	998	2,007	8.5%	102	102	8.5%
National Grid	7,496	12,850	54.4%	653	612	51.0%
NSTAR	5,386	8,617	36.5%	438	400	33.3%
Unitil	16	20	0.1%	1	16	1.3%
WMECO	86	121	0.5%	6	70	5.8%
Total	13,982	23,615	100%	1,200	1,200	100%

As evident in Table 62, the actual survey sample (n=1,202) represents 8.6 percent of total 2010 program participation at the time the survey effort was launched.

Table 62. 2010 RCS – Complete Surveys

PA*	Completed Surveys	Percent of Completed Surveys
National Grid	637	53.0%
NSTAR	437	36.4%
Cape Light Compact	112	9.3%
WMECO	16	1.3%
Total	1,202	100%
*The Unitil program data only contained 16 participants with contact information, and, although efforts were made to reach these participants, none completed the survey.		

Once the final survey data were received, we divided the proportion of the survey to be made up by each PA according to the sampling plan by the proportion of the survey actually made up by each PA. Weighting variables by this value allowed for the survey results to more accurately reflect the sample population stratified by PA. The survey was only stratified by PA, so no further weighting was required.

Gas Weatherization Sampling

Since the 2010 Gas Weatherization participant survey was conducted in early 2011, a complete set of 2010 participants was available for the sample. Similar to our approach to the RCS sampling plan, we calculated an initial survey target for each PA by taking the proportion of the total number of 2010 participants for each PA, multiplied by the target survey population (400). We then adjusted these numbers to satisfy a minimum sample size for each PA of 30 participants or, in cases where this was not possible, a census of participants served as the survey target. The final sample design can be seen in Table 63.

Table 63. 2010 Gas Weatherization - Sampling Design

PA	Actual 2010 Participants Provided	PA Stratification	Unadjusted Survey Target	Adjusted PA Stratification	Adjusted Survey Target
Berkshire Gas	241	3.79%	15	7.50%	30
Columbia Gas	1,712	26.89%	108	23.61%	94
National Grid	3,288	51.65%	207	45.35%	181
New England Gas	82	1.29%	5	7.50%	30
NSTAR	1,036	16.27%	65	14.29%	57
Unitil	7	0.11%	-	1.75%	7
Total	6,366	100.00%	400	100.00%	399

The Evaluation team completed 435 interviews with customers who participated in the 2010 Gas Weatherization program. The interviews were conducted across six Program Administrators in Massachusetts between May 5 and May 15, 2011. For the purposes of this study, Gas Weatherization participants were defined as customers who either had a home energy assessment performed in their homes and took no further action, or those who had a home energy assessment performed and installed weatherization measures recommended by the assessment.

The telephone interviews were conducted using a Computer-Assisted Telephone Interviewing (CATI) system. The final survey dispositions are provided in Table 64.

Table 64: 2010 Gas Weatherization - Survey Dispositions[14]

Disposition	N
Completed Interviews (I)	435
Eligible Non-Interviews	987
Refusals (R)	*437*
Mid-Interview terminate (R)	*76*
Respondent never available (NC)	*460*
Language Problem (NC)	*14*
Not Eligible (e)	355
Fax/Data Line	*15*
Non-Working	*203*
Wrong Number	*70*
Business/Government	*43*
No Eligible Respondent	*24*
Unknown Eligibility Non-Interview (U)	2,285
No Answer	*1,558*
Answering Machine	*676*
Busy	*18*
Call Blocking	*33*
Total Participants in Sample	4,062

The survey response rate is the number of completed interviews divided by the total number of potentially eligible respondents in the sample. We calculated the response rate using the standards and formulas set forth by the American Association for Public Opinion Research (AAPOR).[15] Because we were unable to determine the eligibility of all sample units through the survey process (e.g., due to answering machines and busy signals), we chose to use AAPOR Response Rate 3 (RR3). RR3 includes an estimate of eligibility for these unknown sample units. The formulas used to calculate RR3 are presented below. The definitions of the letters used in the formulas are displayed above in Table 64.

$$E = (I + R + NC) / (I + R + NC + e)$$

[14] Similar information will also be provided for RCS in the next draft of the report. The information could not be generated in time to be included in this version o the report

[15] *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys*, AAPOR, 2009. http://www.aapor.org/Standard_Definitions/1818.htm

$$RR3 = I / ((I + R + NC) + (E*U))$$

We also calculated a cooperation rate, which is the number of completed interviews divided by the total number of eligible sample units actually contacted. In essence, the cooperation rate gives the percentage of participants who completed an interview out of all of the participants with whom we actually spoke. We used AAPOR Cooperation Rate 1 (COOP1) which is calculated as:

$$COOP1 = I / (I + R)$$

Table 65: 2010 Gas Weatherization - Survey Response and Cooperation Rates[16]

AAPOR Rate	Percentage
Response Rate (RR3)	13%
Cooperation Rate	45%

There are multiple sources of non-sampling error that can impact survey results, including non--response error and resulting coverage bias. This type of bias is usually overcome through weighting the survey results to the population of customers targeted by the survey effort. However, in the case of the Mass Save Home Energy Assessment survey participants, the demographic composition of the population is unknown to us, which prevents us from being able to weight the data to account for coverage bias. As a result, the survey data were left unweighted.

Nonparticipant Survey

The Cadmus team completed 401 interviews with nonparticipating customers across eight PAs in Massachusetts between May 3 and May 14, 2011. For the purposes of this study, nonparticipants were defined as utility customers who have not participated in any of the utility-sponsored energy efficiency programs (including energy audits) in Massachusetts in the past three years.[17]

The sample for the survey was drawn from the population of utility customers, less customers that were known to have participated in certain programs.[18] From this sample frame, we drew a stratified random sample of 10,314 customers in Massachusetts to ensure a one to 20 production rate. We stratified the sample proportionately by utility. The summary of our sampling approach is outlined in Table 66.

[16] Similar information will also be provided for RCS in the next draft of the report. The information could not be generated in time to be included in this version of the report

[17] Respondents were not asked about their awareness or participation in the Residential Lighting Program. This is an "upstream" program targeting retailers and manufacturers, so end-use customers may not be aware of whether they've purchased utility-discounted lighting products.

[18] This sample frame was drawn for the first wave of the nonparticipant panel study and was drawn by merging utility Customer Information System (CIS) data with program tracking databases in order to identify and exclude program participants. As part of developing the sample frame, the evaluation team identified and removed duplicate records. Participants of the first wave of the nonparticipant panel study were removed from the sample frame.

Table 66: Nonparticipant - Sampling Approach

Utility Name	Total Population	Targeted Completes	Survey Completes
NGRID	847,893	169	168
NSTAR	793,353	158	161
CLC	179,634	36	35
WMECO	57,440	11	11
Bay State Gas	37,561	7	7
Unitil	27,911	6	6
Berkshire Gas	22,611	5	5
New England Gas	38,276	8	8
Total	1,944,447	400	401

To ensure that participants were not included in the study, we asked survey respondents several screening questions at the beginning of the interview about their participation in the Home Energy Assessment and other energy efficiency programs over the past three years. To screen out Low-Income program participants who might identify community action agencies rather than utilities as the entities installing their energy efficient measures, we asked survey respondents if they had energy efficiency equipment or insulation installed for free during the past three years.

The telephone interviews were conducted using a (CATI) system. The final survey dispositions are in Table 67.

Table 67: Nonparticipant - Survey Dispositions

Disposition	N
Completed Interviews (I)	401
Eligible Non-Interviews	3,949
Refusals (R)	*3,304*
Mid-Interview terminate (R)	*198*
Respondent never available (NC)	*322*
Language Problem (NC)	*125*
Not Eligible (E)	2,006
Fax/Data Line	*60*
Non-Working	*1,491*
Wrong Number	*27*
Business/Government	*161*
Cell Phone	*82*
No Eligible Respondent	*179*
Duplicate number	*6*

Disposition	N
Unknown Eligibility Non-Interview (U)	3,957
Not attempted	*1,434*
No Answer	*1,824*
Answering Machine	*671*
Busy	*16*
Call Blocking	*12*
Total Participants in Sample	401

The survey response rate is the number of completed interviews divided by the total number of potentially eligible respondents in the sample. Again, we calculated the response rate using the standards and formulas set forth by the AAPOR.

Table 68: Nonparticipant - Survey Response and Cooperation Rates

AAPOR Rate	Percentage
Response Rate (RR3)	6%
Cooperation Rate	10%

There are multiple sources of non-sampling error that can impact survey results, including non--response error and resulting coverage bias. This type of bias is usually overcome through weighting the survey results to the population of customers targeted by the survey effort. Since the demographic composition of the nonparticipant population is unknown to us, weighting of the nonparticipant sample alone is impossible.

To overcome this barrier we collected demographic characteristics for all respondents, including those who are disqualified from the survey because they participated in at least one program. This approach allowed us to weight all respondents – including those that are disqualified from the survey because they participated in a program – back up the population of Massachusetts, for which demographic and other data are known, and thus correct for non-response bias among nonparticipants. In addition, this approach provided a more accurate assessment of the demographic and household characteristics of the nonparticipant sample.

Review of the survey results showed that the sample underrepresented young people, renters, and those with less education. Because these personal characteristics are likely to be associated with the behaviors and attitudes that influence program participation, we constructed a survey weight based on these three characteristics. Final data were weighted by these three variables. We constructed the weight in two stages:

- At the first stage, we applied weights by age and education using the categories outlined in Table 69.

Table 69: Nonparticipant Weighting – Stage 1

	Massachusetts Population	Nonparticipant Data	Weight
18-34 years:			
High School or less	10%	3%	3.67
Some college, no degree	8%	3%	2.92
Associate's degree	2%	1%	2.01
Bachelor's degree	7%	6%	1.21
Graduate or professional degree	3%	5%	0.58
35 to 44 years:			
High School or less	7%	2%	2.67
Some college, no degree	3%	2%	2.00
Associate's degree	2%	2%	0.82
Bachelor's degree	5%	6%	0.76
Graduate or professional degree	3%	Appendix A: 4%	Appendix B: 0.83
Appendix C: 45 to 64 years:			
Appendix D: High School or less	Appendix E: 12%	Appendix F: 8%	Appendix G: 1.53
Appendix H: Some college, no degree	Appendix I: 6%	Appendix J: 8%	Appendix K: 0.74
Appendix L: Associate's degree	Appendix M: 3%	Appendix N: 4%	Appendix O: 0.85
Appendix P: Bachelor's degree	Appendix Q: 7%	Appendix R: 12%	Appendix S: 0.57
Appendix T: Graduate or professional degree	Appendix U: 6%	Appendix V: 12%	Appendix W: 0.50
Appendix X: 65 years and over:			
Appendix Y: High School or less	Appendix Z: 10%	Appendix AA: 8%	Appendix BB: 1.21
Appendix CC: Some college, no degree	Appendix DD: 2%	Appendix EE: 3%	Appendix FF: 0.78
Appendix GG: Associate's degree	Appendix HH: 1%	Appendix II: 2%	Appendix JJ: 0.53
Appendix KK: Bachelor's degree	Appendix LL: 2%	Appendix MM: 6%	Appendix NN: 0.36
Appendix OO: Graduate or professional degree	Appendix PP: 2%	Appendix QQ: 5%	Appendix RR: 0.42

- We then applied a second weight adjusting for home ownership status as shown in the table below:

Table 70: Nonparticipant Weighting – Stage 2

	Massachusetts Population	Nonparticipant Data	Weight
Home Ownership Status			
Rent	36%	27%	1.33
Own	64%	73%	0.88

Our final weights ranged from 0.29 to 4.59. Finally, we checked the size of the unequal weighting effect (UWE) for the applied weight adjustment factors to make sure it was not unreasonably large.[19] The UWE was just under 2, which we deemed reasonable.

[19] The UWE is calculated as 1 + (Coefficient of Variation)^2 , where the Coefficient of Variation is the standard deviation of the weight variable divided by the average weight (which by definition is about 1.0).