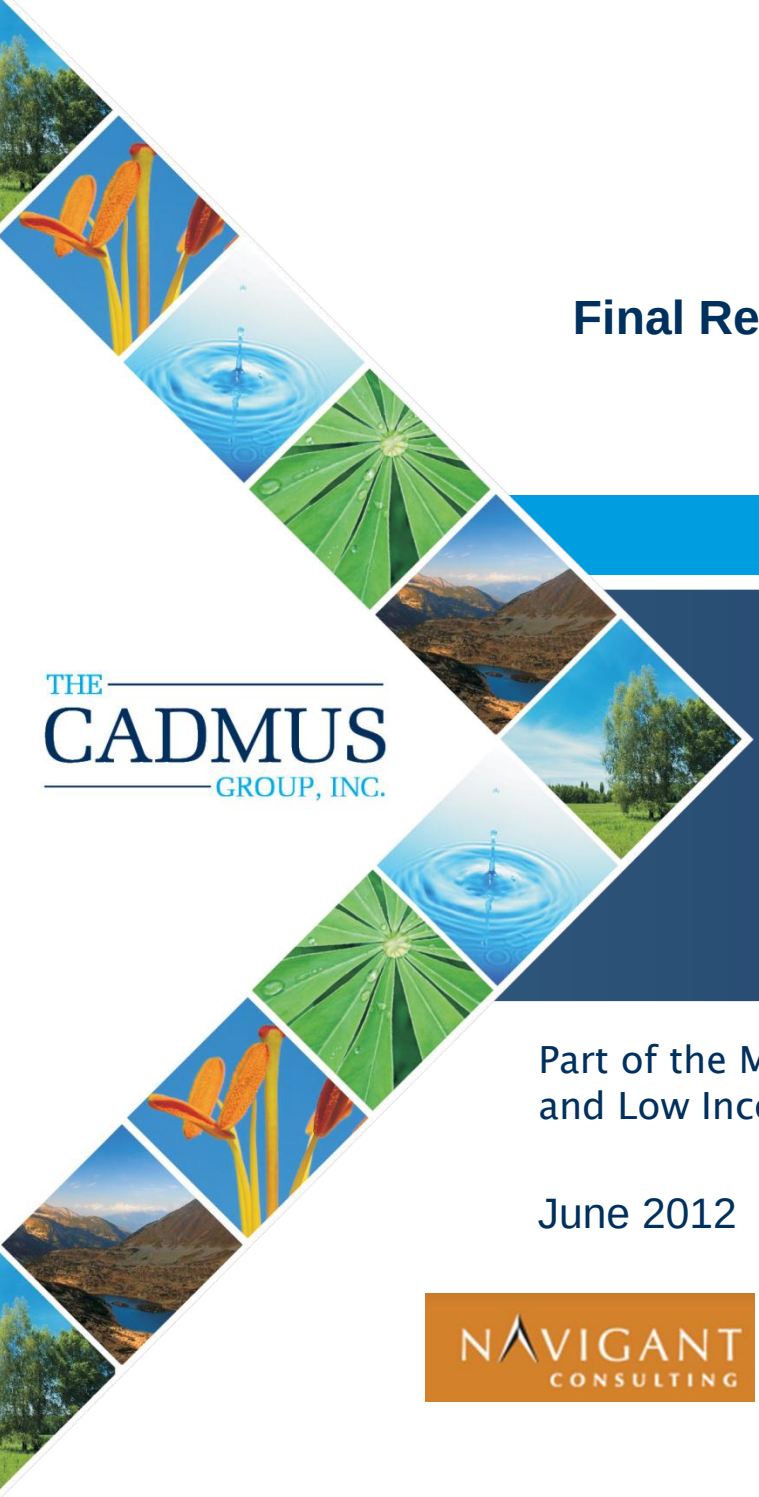

THE CADMUS GROUP, INC.

Final Report

Home Energy Services Net-to-Gross Evaluation

Part of the Massachusetts Residential Retrofit and Low Income Program Area Evaluation

June 2012

NAVIGANT CONSULTING | OPINION DYNAMICS CORPORATION | Itron | ers

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Acronym Glossary

Acronym	Full Name
ACS	American Community Survey
AIC	Akaike's Information Criterion
CFL	Compact fluorescent light
CSR	Customer self-report
DC	Discrete choice (statistical market share modeling)
DSM	Demand-side management
FR	Free-riders
HES	Home Energy Services
NPS	Non-participant spillover
NTG	Net-to-gross
PA	Program administrator
PS	Participant spillover
RASS	Massachusetts Residential Appliance Saturation Survey
RCS	Residential Conservation Services

Executive Summary

This report summarizes the 2011 Home Energy Services (HES) Program net-to-gross (NTG) impacts. This evaluation was conducted by The Cadmus Group, Inc., Opinion Dynamics, Navigant Consulting, Itron, and Energy and Resource Solutions, collectively referred to as The Evaluation Team

We based our evaluation findings, conclusions, and recommendations on results from an array of data collection activities and evaluation tasks, including participant and non-participant[1] surveys and self-report and discrete choice (DC)-based assessments of measure-level NTG ratios.

Methodology

The Evaluation Team estimated measure-specific NTG ratios using the two approaches listed below. Collectively, these approaches allowed us to estimate participant free-ridership and spillover, as well as non-participant spillover for select measures. These approaches were both informed by surveys with 1,200 participants and 1,202 non-participants:

1. ***Customer Self-Report (CSR):*** The surveys allowed us to estimate participant free-ridership, participant spillover, and non-participant spillover. We defined each estimate as follows:
   a. ***Free-riders (FR)****:* Program participants that received free or incentive-eligible measures that would have installed the same measures in the program's absence; FR reduces the amount of savings attributable to the HES Program.
   b. ***Participant Spillover (PS)****:* Savings generated by participant's decisions to invest in additional efficiency measures or activities due to their participation in HES, without the assistance of program incentives; PS increases the amount of savings attributable to the program. PS includes only *like* measures; that is, only savings from other HES Program measures installed outside of the HES Program.
   c. ***Non-participant Spillover (NPS)****:* Program-qualifying measures that customers install independently of the program after being influenced by program education and marketing efforts; NPS increases the amount of savings attributable to the program.
2. ***Statistical Market Share Modeling or Discrete Choice (DC):*** We used a mixed logit model to evaluate the HES Program's marketing and incentive impacts on consumer decisions regarding energy-efficiency investments.

Table ES-1 summarizes the applicable evaluation methodologies by measure and NTG component. We derived our NTG estimates as the sum of individual components (NTG = 1 – FR + PS + NPS). In many cases, we estimated the individual NTG components (FR, PS, and NPS) using only the CSR approach. However, for NTG components where both the CSR and DC

[1] HES non-participants are defined as non-low-income residents who live in a single family home (structures with one to four units) and who have not received a free audit or energy-efficiency incentive over the past two years through any PA program.

approach were available (such as for air leak sealing and insulation measures), we developed a composite estimate using a simple average of the two approaches.

Table ES-1. NTG Component Estimation by Measure

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover
Direct Installs	CFL	CSR	CSR	CSR
	Air Leak Sealing	CSR, DC	CSR	CSR, DC
Measures for which an Incentive was Offered	Insulation	CSR, DC	CSR	CSR, DC
	Refrigerator	CSR	CSR	CSR

Results

Table ES-2 presents NTG findings, by measure and overall, for the 2011 HES Program. We estimated the program-level NTG to be 113%. We are not reporting the NTG components that overlap with other programs, such as CFL NPS and refrigerator PS, which would double count the impacts of the concurrent Upstream Lighting and ENERGY STAR® Appliance Rebate programs. Table ES-2 shows N/R, indicating Not Reported, for the relevant components of those measures. We also did not collect data on refrigerator installations on our non-participant survey. Thus, Table ES-2 shows N/A, indicating Not Available, for refrigerator NPS.

Table ES-2. 2011 HES NTG Findings

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG	90% Confidence Bounds
Direct Installs	CFL	29%	2.5%	N/R	73%	2%
	Air Sealing	8%	8%	28%	129%	21%
Measures for which an Incentive was Offered	Insulation	25%	20%	28%	123%	14%
	Refrigerator	14%	N/R	N/A*	86%	10%
Overall					**113%**	**9%**

Note: N/R = Not Reported, N/A = Not Available

* We did not collect data on refrigerator installations with our non-participant survey.

The following bullets outline additional information related to the composite estimates, with additional detail described in the Results section of this report.

- ***Free-ridership Estimation for Identical HES Electric and Gas Program Measures***. Our estimate of free-ridership is based on an aggregated sample, combining responses from all heating fuel types.
- ***Combining CSR and DC Estimates***. Similar to our 2010 evaluation, we used a simple average of CSR and DC estimates where both were available.

- ***Overlap with Other Programs*.** As noted above, we are not reporting NTG components that overlap with other programs, such as CFL NPS and refrigerator PS, which would double count the impacts of the concurrent Upstream Lighting and ENERGY STAR Appliance Rebate programs.
- ***Confidence Bounds.*** We calculated confidence bounds around the measure-level NTG estimates by combining the confidence bounds for each individual estimate (CSR and DC).

It is important to keep the following four caveats in mind when using these evaluation results:

1. The Evaluation Team has provided the most accurate point estimate of NTG possible given the available information and the methods that we used. There is some subjectivity in our approach to estimating NTG, but no methods exist for quantifying the magnitude of any systematic error that may be inherent in our approach.[2]
2. The NTG values we determined are applicable to HES in Massachusetts. However, they are not applicable for other types of programs, such as the Low Income or Multifamily programs, given the very real differences in market actors and customers' energy-efficiency decision-making in the segments targeted by the various programs.
3. As the design of the HES Program changes and the energy-efficiency knowledge and practices of market actors evolve, we expect the NTG results to change. For example, in 2010, some of the program administrators (PAs) provided insulation incentives without an audit, but that practice was terminated. Also, we estimated PS and NPS for more measures in this 2011 HES evaluation than in the 2010 evaluation, creating measure-level changes in NTG.
4. The overall NTG of 113% is a weighted average of the measure-specific NTG values listed in Table ES-2, which is based on estimated measure-level statewide energy savings in 2011. The overall NTG will differ for each PA based on their specific distribution of measures installed in 2011. Likewise, any application of the NTG estimates for planning purposes should consider the implications of changes in program design or measure distribution over time.

[2] This uncertainty is very different than the uncertainty related to 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, but the magnitude of this uncertainty relative to the methodology and scoring choices made by energy-efficiency professionals is unknown.

Program Overview

The Home Energy Services (HES) Program has been in place since the early 1980s, targeting non-low-income residential customers living in single family houses or multifamily buildings with one to four units.[3] The program offers home energy audits to participating customers, regardless of their heating fuel type. Through these audits, technicians identify opportunities for the customers to save energy through a variety of home improvements, including:

- Building envelope measures, such as insulation and air sealing
- Heating system replacements, such as furnace and boilers
- Heating distribution systems, such as duct and pipe insulation
- Thermostats
- Boiler reset controls
- Lighting
- Refrigerator removal and replacement
- Water heating measures, such as low-flow showerheads and aerators
- Water heating system replacements, such as on-demand and indirect water heaters

The PAs' primary goal for the program is to achieve significant energy savings by promoting a whole-house approach, and by offering education, incentives, and financing options for gas and electric measures. All cost-effective, energy-saving improvements are targeted.

By calling the program hotline or a PA's customer service line, customers are screened for qualification and then directed to the correct program and services (outlined below). Technicians provide these services over several visits.

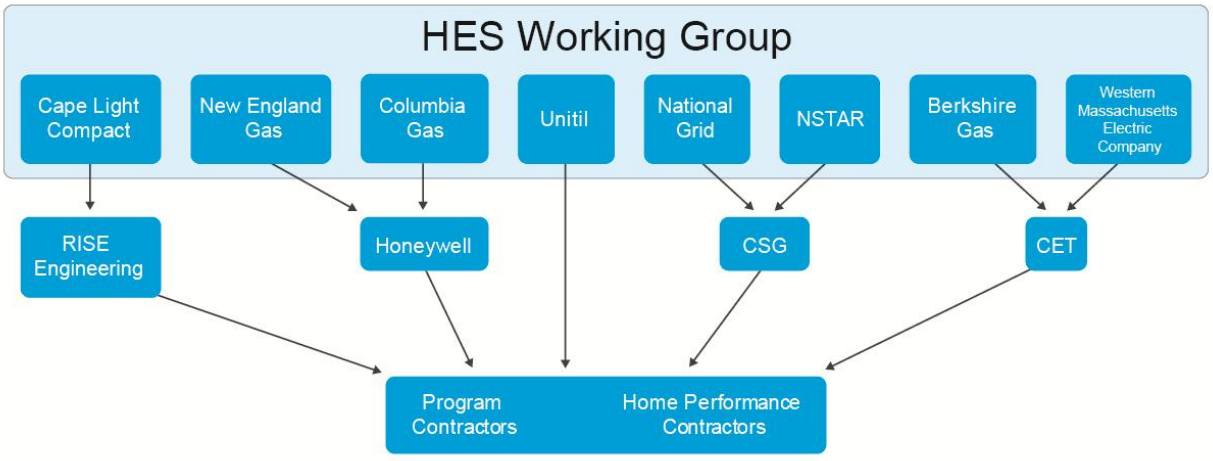
- ***Screening and Diagnostic Visit.*** During the initial high-level audit, the technician installs various free measures (e.g., compact fluorescence lights (CFLs), low-flow showerheads, faucet aerators), and either conducts the diagnostic tests or encourages the customer to schedule a diagnostic visit. During the diagnostic visit, the technician conducts area blower door test, infrared scanning, duct testing, and, when feasible, installs—at no cost to the customer—air sealing, duct sealing, and programmable thermostats. Also during this visit, the technician: (1) recommends specific energy-efficient upgrades that require a professional program contractor and a co-pay from the customer; and (2) provides information regarding available, energy-efficiency financial incentives offered through the relevant PA.

[3] Prior to 2010, the HES Program was commonly referred to as the Mass Save® Program, which is the name it is known as by the majority of PAs, vendors, contractors, and participants. In 2010 Mass Save was transitioned into the overarching brand used for Massachusetts' efficiency programs umbrella marketing efforts.

- ***Installation Visit.*** If the customer decides to have additional energy-efficient measures and upgrades installed, program contractors conduct the specified work in one or several visits, depending on the customer's needs.
- ***Quality Assurance Visit.*** The quality assurance component of this process is currently conducted via one site visit and, in some cases, is followed up with a phone survey, postcard, or e-mail to ensure all measures were installed properly.

In recent years, the PAs have put significant effort into standardizing the HES Program across Massachusetts and implementing Mass Save® such that customers can easily access all PA efficiency offers, thereby experiencing one program as opposed to multiple offerings. Figure 1 illustrates how several PAs interact within the program structure. As evident in the figure, the PAs collectively formed the Residential Conservation Services (RCS) Working Group, and collectively subcontract with four different Mass Save vendors.

Figure 1. Mass Save® Program Structure



Net Savings

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

- ***Free-riders (FR)****:* Program participants that received free measures or an incentive for measures and would have installed the same measures in the program's absence; FR reduces the amount of savings attributable to the HES Program.
- ***Participant Spillover (PS)****:* Additional savings generated by customers' decisions to investing additional efficiency measures or activities due to their program participation, without the assistance of program incentives; PS increases the amount of savings attributable to the program.PS includes only *like* measures; that is, only savings from other HES Program measures installed outside of the HES Program are attributed to PS.
- ***Non-participant Spillover (NPS)****:* Program-qualifying measures that customers install independently of the program after being influenced by program education and marketing efforts; NPS increases the amount of savings attributable to the program.

The NTG value combines the above components as follows:

$$NTG = 1 – FR + PS + NPS$$

Background

There are no best practices for determining net-to-gross (NTG) analysis in the demand-side management (DSM) industry. Consequently, energy-efficiency stakeholders across the country handle NTG differently. For example, as of 2008, regulators in 15 states simply assume that free-ridership and spillover offset one another in determining program cost-effectiveness.[4] Conversely, as of 2012 California only accounts for free-ridership, which is trued up by the *ex post* evaluation, but does not consider spillover of any sort. Several northeastern states, including Connecticut, Massachusetts, New York, and Vermont, require the estimation of all major NTG components.

[4] Quantec, et al. *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. February 15, 2008.

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

- ***CSR***, where surveys are used to determine whether participants are FR or exhibit PS behavior, and whether non-participants were influenced by the program 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 the 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 that reveals, rather than states, free-ridership and spillover. Most commonly, this method uses Discrete Choice (DC) models.
- ***Trade Ally/Market Actor Research***, designed to gather free-ridership and spillover information from the perspectives of market actors or through analysis of market data.

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

Recognizing these issues, we designed a NTG evaluation approach addressing the 2010–2012 period in which we obtained NTG estimates from complementary approaches while working within resource constraints. This required a staggered implementation of the various approaches over time.

Methodology

We based the 2011 HES Program NTG estimates on two combined approaches: CSR and DC. A high-level description of the methodology for each approach is provided below, while significant details (include logic flow charts) are provided in Appendix A.

Customer Self-Reports

The Evaluation Team determined CSR FR, PS, and NPS through surveys of 2011 HES participants and non-participants.[5] The program measures we discussed with the participants and non-participants during surveys are shown in Table 1.

[5] For the purpose of the surveys, we defined HES non-participants as non-low-income residents who live in a single family home (structures with one to four units) and who had not received a free audit or energy-efficiency incentive during the past two years.

Table 1. HES Program Measures by Survey

Measure Category	Measure	Participant Survey (n=1,200)	Non-participant Survey (n=1,202)
Direct Installs	CFL	√	√
	Air Sealing	√	√
Measures for which an Incentive was Offered	Insulation	√	√
	Refrigerator	√	

Participant Free-ridership

We used a battery of survey questions for each measure category to calculate free-ridership, or the percentage of savings that would have occurred in the program's absence. Collectively, the questions allowed us to estimate the influence of the HES Program on participants' decision-making processes, which we then used to determine the likelihood that the measure would have been installed in the program's absence. Specifically, we included the following questions in the survey to determine free-ridership:

- 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?
- What was the self-assessed likelihood the participant would have installed free measures or program measures for which they received an incentive outside the HES Program?

A critical component of the CSR free-ridership methodology is assigning how influential the program was on the participant's decision to install the measure in question. If survey participants reported the program being very influential or somewhat influential on their decision to install the measure, we identified the respondent as a non-freerider. If a respondent said the program was not very influential, we classified them as a partial FR. We classified respondents who said the program was not at all influential as non-FR.

To illustrate how we used each battery of questions to estimate free-ridership, we created a logic model diagram for each measure category. These are reported in Appendix A.

Participant Spillover

We estimated PS by asking participating customers if they decided to install additional energy-efficiency measures after participating in the program. To tie these purported actions to their participation in the HES 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 questions:

1. Since participating in the program, has the participant installed additional energy-efficient equipment not offered with an incentive through a PA program?
2. What additional energy-efficient equipment was installed (and what quantity)?
3. How influential was the program in the participant's decision to install additional energy-efficient equipment in their home?

Using a process similar to estimating free-ridership, we determined PS by gauging the program's relative influence on customers' decisions to pursue these additional energy saving measures.

Table 14 in the Participant Spillover Methodology section of Appendix A contains our calculations for estimated PS.

Non-participant Spillover

We estimated CSR NPS for insulation, air sealing, and CFL program measures. We asked non-participants if they had insulated their home, added air sealing, or installed CFLs within the past two years. For each measure a respondent mentioned installing, we asked them if they learned about the program before, after, or at the same time as their purchase.

We did not attribute respondents to NPS who said they learned about the program after they purchased the measure. We asked respondents who learned about the program at the same time or before purchasing the measure why they did not apply for an incentive through the HES Program. We did not attribute respondents' actions to NPS if they gave one of the following responses for not applying for an incentive:

- Their measure did not qualify for an incentive.
- They actually did receive a Mass Save incentive.
- They were not aware of the HES Program at the time of the measure purchase (contrary to what they said before).

We asked respondents whether they did not apply for a program incentive due to one of the following reasons:

- It was a hassle or it takes too long
- They did not want to bother submitting the forms
- The amount of money was not worth it
- They were not aware that the program offered an incentive

- Just did not apply/did not want to apply/forgot to apply
- Income/tax-related reasons

We also asked respondents how influential the information they learned through the HES Program was on their decision to purchase the measure. If a respondent said what they learned through the HES Program was very influential on their purchasing decision, we attributed the measures they installed to program NPS. If they said HES Program information was somewhat, not very, or not at all influential, we did not attribute the measures they installed to NPS.

Diagram 5 in the Non-participant Spillover Methodology section of Appendix A illustrates the methodology we applied to determine NPS actions, and it contains the logic flow for this analysis approach.

Statistical Market Share Modeling

In parallel to the CSR method, The Evaluation Team used DC modeling to estimate free-ridership and NPS for insulation measures installed under the HES Program. These types of models are employed in a variety of market research settings for determining how various factors influence consumer behavior. For the present application, we used a mixed logit model to evaluate the HES Program marketing and incentive impact on consumer decisions regarding energy-efficiency investments.

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

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

The first part, $\mathbf{V(j)}$, represents the portion of the individual's utility function that is known to the researcher, in that it is a function of traits the researcher has observed. For instance, an individual's decision about whether or not to purchase insulation may be represented as a function of the following:

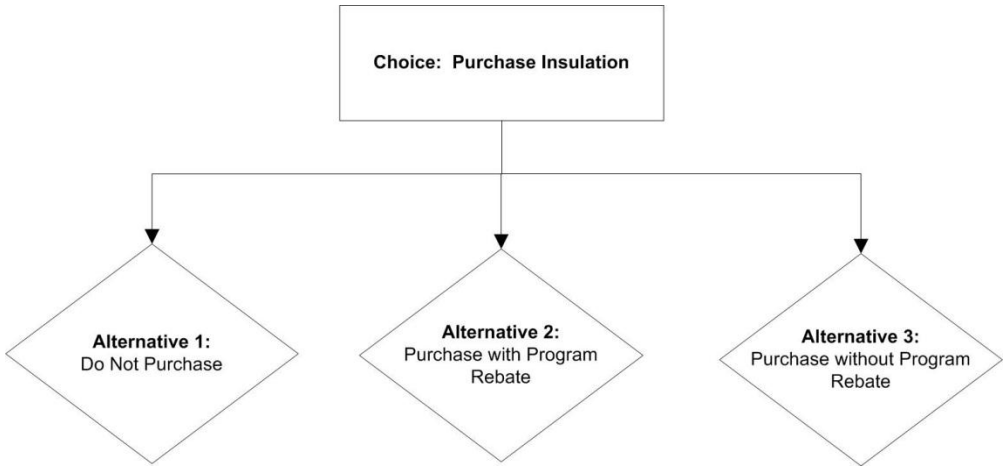
- Demographics (e.g., age of customer, homeownership status)
- Characteristics of home (e.g., age of home, heating fuel type)
- Attitudes about energy efficiency
- Dollar value of insulation incentives
- Program awareness and influence

The second component of the individual's utility function, $\epsilon(\mathbf{j})$, is considered the portion researchers cannot account for, and it is modeled as being random. Different types of DC models are largely distinguished by their different assumptions regarding the joint distribution of $\epsilon(\mathbf{j})$.

For a given specification of explanatory variables believed to influence a customer's decision, we fit the utility function's parameters to a dataset via the maximum likelihood or a similar method. Based on the fitted parameters, we estimated the probability of an individual choosing one option or another as a function of their explanatory variables.

We considered three alternatives in our model that each customer (participants and non-participants) faced when deciding whether or not to purchase insulation or air-sealing measures. The mixed logit model estimates the probability of an individual choosing one of the three alternatives, as illustrated for HES insulation in Figure 2.

Figure 2. Discrete Choice Model Alternatives – Insulation Measures



Other Data

In addition to using the aforementioned participant and non-participant surveys, The Evaluation Team assembled HES Program tracking and audit data from the Massachusetts PAs (Berkshire Gas, Cape Light Compact, Columbia Gas, National Grid, New England Gas, NSTAR, Unitil, and Western Massachusetts Electric Company). We used these data to determine the insulation quantity, cost, incentive, and energy savings for each participant.

The Evaluation Team combined data from the sources noted above and created several additional variables specifically for our DC analyses (shown in Table 2).

Table 2. Modeling Variables Created from Surveys and Program Tracking Data

Name	Description
Age	Age of survey respondent
Ads	Number of HES advertisements that respondent could recall (0, 1, etc.)
Alt2*	Alternative 2-specific constant (1=alternative 2, 0=otherwise)
Alt3*	Alternative 3-specific constant (1=alternative 3, 0=otherwise)
EE_Very_Knowledgeable	Respondent is very knowledgeable about energy efficiency (1=yes, 0=no)
Gas_Heat	Respondent has gas heat (1=yes, 0=no)
HES_Influence	Index of HES Program awareness and influence
Home_Age	Age of home
Home_Own	Respondent owns their home (1=yes, 0=no)
Incentive	Insulation incentive amount in dollars
Motive_Comfort	Comfort of home is an energy-efficiency motivation (1=yes, 0=no)
Non_Part	Respondent is an HES non-participant (1=yes, 0=no)
Gas_Heat x Alt2	Interaction of Gas_Heat and Alt2 constants
HES_Influence x Ads x Alt2	Interaction of HES_Influence, the number of Ads, and Alt2 constants
Home_Age x Alt2	Interaction of Home_Age and Alt2 constants
Incentive x Alt2	Interaction of Incentive and Alt2 constants
Gas_Heat x Alt3	Interaction of Gas_Heat and Alt3 constants
HES_Influence x Ads x Alt3	Interaction of HES_Influence, the number of Ads, and Alt3 constants
Non-Part x Home_Own x Alt3	Interaction of Non_Part, Home_Own, and Alt3 constants

* As shown in Figure 2, Alternative 2 indicates being purchased with a program incentive, and Alternative 3 indicates being purchased without a program incentive.

We interacted several of the variables with specific alternatives to ensure that the coefficients in the model could be identified, and because the impacts of a given variable on an individual's utility function can vary across alternatives. For example, assume there is a variable that takes the same value for all three choice alternatives, for each respondent. This variable's effect on decision making cannot be captured by a DC model, as its impact on a customer's utility function is the same for each option. However, the *differences* among the alternative decisions drive these respondents' utility functions, and ultimately the customer decisions. For example, we allowed the presence of gas heat in a home to have a different amount of influence in participant and non-participant customer's decision making by specifying interaction terms with each of the purchase alternatives shown in Table 2.

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

1. We weighted each individual used in the development of the mixed logit model to correct for non-participant sample bias. The survey results showed that relative to the general population, the non-participant sample under-represented young people, renters, and those with less education. Because these personal characteristics are likely to be associated with the behaviors and attitudes influencing program participation, we based our non-participant survey weights on these three characteristics.

   We considered other weighting schemes to control for non-participant energy-efficiency attitudes, but our research did not identify any studies using similar methods on a similar population that controlled for response bias in this manner.

Participant survey responses are representative of the HES Program population, so we gave all responses an equal weight.

2. The SAS implementation of the mixed logit model (multinomial CD) does not accept direct sample weights; we therefore used respondent replication to account for the described non-participant survey weights.[6] Table 3 summarizes the number of insulation respondents we used in the final modeling dataset, grouped by the alternative each respondent actually selected.

Table 3. Number of Respondents and Weighting in Final Modeling Data by Chosen Alternative – Insulation

Alternative	Chosen Alternative	N	Sum of Weights
1	No Purchase	1,321	4,017
2	Purchased Through HES Program	255	747
3	Purchased Outside of HES Program	249	680

Application of Multiple Approaches

The final participant free-ridership, PS, NPS, and NTG values are composite estimates of the various research methods we employed. Table 4 summarizes the applicable methodologies that were available by measure and NTG component for the 2011 HES Program.

Table 4. 2011 HES NTG Component Estimation by Measure

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover
Direct Installs	CFL	CSR	CSR	CSR
	Air Sealing	CSR, DC	CSR	CSR, DC
Measures for which an Incentive was Offered	Insulation	CSR, DC	CSR	CSR, DC
	Refrigerator	CSR	CSR	CSR

[6] For example, we replicated the data for respondents with a weight of 2 such that the same record appears in the final modeling dataset two times.

Results

Table 5 presents the NTG findings, by measure and overall, for the 2011 HES Program. We estimated the program-level NTG to be 113%. We are not reporting NTG components that overlap with other programs, such as CFL NPS and refrigerator PS, which would double count the impacts of the concurrent Upstream Lighting and ENERGY STAR Appliance Rebate programs. Table 5 shows N/R, indicating Not Reported, for the relevant components of those measures. We also did not collect data on refrigerator installations on our non-participant survey. Thus, Table 5 shows N/A, indicating Not Available, for refrigerator NPS.

Table 5. 2011 HES NTG Findings

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG Estimate	NTG 90% Confidence Bounds
Direct Installs	CFL	29%	2.5%	N/R	73%	2%
	Air Sealing	8%	8%	28%	129%	21%
Measures for which an Incentive was Offered	Insulation	25%	20%	28%	123%	14%
	Refrigerator	14%	N/R	N/A*	86%	10%
Overall					**113%**	**9%**

Note: N/R = Not Reported, N/A = Not Available.

* We did not collect data on refrigerator installations with our non-participant survey.

The following bullets outline additional information related to the composite estimates:

- ***Free-ridership Estimation for Identical HES Electric and Gas Program Measures***. Although we estimated free-ridership separately for each measure by heating fuel type (gas or electric/other), our recommended estimate of free-ridership is based on an aggregated sample. This increased the sample size and avoided having different estimates for the same measure across fuel types. Furthermore, measure-level free-ridership is similar across fuel types. Appendix B contains additional details on measure-level free-ridership by heating fuel type.
- ***Combining CSR and DC Estimates***. We used a simple average of CSR and DC estimates where both were available. For example, our composite air sealing free-ridership estimate of 8% is based on a simple average of the CSR (7%) and DC free-ridership analyses (8%). Similar to our 2010 evaluation, we calculated a simple average of our two approaches to develop the composite estimates of NTG. This estimate does not implicitly assume that one approach is preferable to the other.
- ***Overlap with Other Programs.*** As noted above, we are not reporting NTG components that overlap with other programs, such as CFL NPS and refrigerator PS. While many HES non-participants reported installing CFLs in 2011, attributing those savings to HES would double count CFL savings captured by the concurrent Upstream Lighting Program. Similarly, PS for the refrigerator replacement measure (as self-identified in the participant surveys) is confounded by the impacts of the ENERGY STAR Appliance Rebate Program. These non-reported NTG components are shown as N/R in Table 5.

- ***Confidence Bounds.*** We calculated confidence bounds around the measure-level NTG estimates by combining the confidence bounds for each individual estimate (CSR and DC), which is consistent with using a simple average to combine the point estimates. We calculated the combined standard error as the square root of the weighted, squared sum of the individual standard errors, as shown in the following equation:

$$SE_{Combined} = \sqrt{\left(\frac{1}{2}SE_{CSR}\right)^2 + \left(\frac{1}{2}SE_{DC}\right)^2}$$

  We used a similar approach to combine measure-level confidence intervals into a program-level confidence interval; however, the measure-level weights are based on a statewide distribution of measures installed rather than being equal to one another.

It is important to keep the following four caveats in mind when using these evaluation results:

1. The Evaluation Team has provided the most accurate point estimate of NTG possible given the available information and the methods that we used. There is some subjectivity in our approach to estimating NTG, but no methods exist for quantifying the magnitude of any systematic error that may be inherent in our approach.[7]
2. The NTG values we determined are applicable to HES in Massachusetts. However, they are not applicable for other types of programs, such as the Low Income or Multifamily programs, given the very real differences in market actors and customers' energy-efficiency decision making in the segments targeted by those programs.
3. As the design of the HES Program changes and the energy-efficiency knowledge and practices of market actors evolve, we expect the NTG results to change. For example, in 2010, some of the PAs provided insulation incentives without an audit, but that practice has been terminated. Also, this 2011 HES evaluation has PS and NPS estimates for measures that were not available in the 2010 evaluation, creating measure-level changes in NTG.
4. The overall NTG of 113% is a weighted average of the measure-specific NTG values listed in Table 5. We based the measure-level weights on estimated statewide measure-level energy savings in 2011. For this estimate, we used 2010 PA-reported measure savings and the number of installations in 2011 from the PA's program tracking data. The overall NTG will differ for each PA based on their specific distribution of measures installed in 2011. Likewise, any application of the NTG estimates for planning purposes should consider the implications of changes in program design or measure distribution over time.

Customer Self-Report and Discrete Choice Results

Summary results from our CSR and DC NTG analyses are shown in Table 6 and Table 7, respectively. As previously mentioned, we combined the components shown in these tables to obtain the results shown in the Executive Summary and at the beginning of this section.

[7] This uncertainty is very different than the uncertainty related to 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, but the magnitude of this uncertainty relative to the methodology and scoring choices made by energy-efficiency professionals is unknown.

Additional details on the calculations we used to develop these values can be found in the appendices.

Table 6. Customer Self-Report NTG Components

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG	NTG 90% Confidence Bounds
Direct Installs	CFL	29%	2%	N/R	73%	2%
	Air Sealing	8%	8%	39%	138%	40%
Measures for which an Incentive was Offered	Insulation	4%	20%	18%	134%	18%
	Refrigerator	14%	N/R	N/A	86%	10%

Note: N/R = Not Reported, N/A = Not Available.

Table 7. Discrete Choice NTG Components

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG	NTG 90% Confidence Bounds
Direct Installs	Air Sealing	7%	N/A	18%	111%	12%
Measures for which an Incentive was Offered	Insulation	46%	N/A	38%	92%	20%

Note: N/R = Not Reported, N/A = Not Available.

Comparison to 2010 Results

Table 8 and Table 9 show the NTG components of the 2011 and 2010 evaluations, respectively, for comparison.

Table 8. 2011 HES NTG Findings

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG
Direct Installs	CFL	29%	2.5%	N/R	73%
	Air Sealing	8%	8%	28%	129%
Measures for which an Incentive was Offered	Insulation	25%	20%	28%	123%
	Refrigerator	14%	N/R	N/A	86%
	Water Heater	N/A	N/A	N/A	N/A
	Heating System	N/A	N/A	N/A	N/A
Overall					**113%**

Note: N/R = Not Reported, N/A = Not Available.

Table 9. 2010 HES NTG Findings

Measure Category	Measure	Participant Free-ridership	Participant Spillover	Non-participant Spillover	NTG
Direct Installs	CFL	22%	19%	N/A	97%
	Air Sealing	7%	N/A	N/A	93%
Measures for which an Incentive was Offered	Insulation	20%	8%	50%	138%
	Refrigerator	5%	N/A	N/A	95%
	Water Heater	25%	N/A	N/A	75%
	Heating System	28%	N/A	N/A	72%
Overall					**112%**

Note: N/R = Not Reported, N/A = Not Available.

At a program level, our 2011 NTG estimate is similar to our 2010 estimate (113% in 2011 vs. 112% in 2010). Although the program-level NTG values are similar, the following are several year-over-year differences at the measure level:

- CFL NTG is lower in our 2011 evaluation because PS decreased from 2010 to 2011. Compared to 2010, fewer 2011 participant survey respondents said that they had purchased non-program CFL bulbs that were highly influenced by the HES Program.
- We were able to evaluate the PS and NPS components for the HES air sealing measure in our 2011 evaluation. The addition of these components accounts for the year-over-year increase in NTG from 93% to 129%.
- The insulation NTG was slightly higher in 2010 (138% vs. 123% in 2011), driven by the lower NPS estimate in our 2011 DC model.
- We did not include water heating or heating system NTG in the 2011 HES evaluation. These measures are provided by the High Efficiency Heating and Water Heating Program, and thus we will include their NTGs in our evaluation of that program.

Appendix A. Details Regarding Participant Self-Report Free-ridership and Spillover Methodology

Free-ridership

The Evaluation Team developed a matrix approach to assign a free-ridership score to each participant based on their objective responses to the battery of survey questions. We assigned scores on question response patterns, and calculated the confidence and precision estimates based on the distribution of these scores.

Our approach provided other important features, including:

- Derivation of a partial free-ridership 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 that quantitative scores matched respondents' more detailed explanations regarding program attribution.
- The ability to change weightings in "what if" scenarios to test the response sets' stability.

The Evaluation Team's method of determining free-ridership offered a key advantage by introducing the concept of partial free-ridership. Experience has taught us that program participants do not fall neatly into FR and non-FR categories. For example, we assigned partial free-ridership scores to participants who reported having had plans to install a given measure, but did so sooner because of the program. In addition, with partial free-ridership, we utilized Don't Know and Refused responses to survey questions, rather than removing the entire respondent from the analysis.

We assessed free-ridership following three steps. First, we converted each possible survey response into free-ridership matrix terminology. Second, we assigned each participant's combination of responses with a score from the matrix. Finally, we aggregated all the participants into an average free-ridership score for the entire measure category.

Participant Self-Report Free-ridership Logic Models

Diagram 1 (CFLs), Diagram 2(air leak sealing), Diagram 3 (insulation), and Diagram 4 (heating systems, water heaters, and refrigerators) show logic models The Evaluation Team developed for assessing HES Program free-ridership for electric and gas participants.

The Evaluation Team assigned a free-ridership score to all possible survey response combinations by 1/8 and 1/4 increments (12.5%, 25%, 50%, 75%, and 100%). A survey respondent receiving a score of 100% is a 100% FR. Likewise, a score of 0% indicates that the respondent was not a FR. Scores between 0% and 100% indicate partial FR.

In the diagrams, a respondent may not persist through the full logic model. For example, in the measures for which an incentive was offered survey questions appearing in Diagram 3 and

Diagram 4, we did not ask additional questions of respondents who answered No to the first free-ridership question, as they were automatically assigned as a 0% free-ridership.

Diagram 1. CFL Direct Install Free-ridership Logic Model

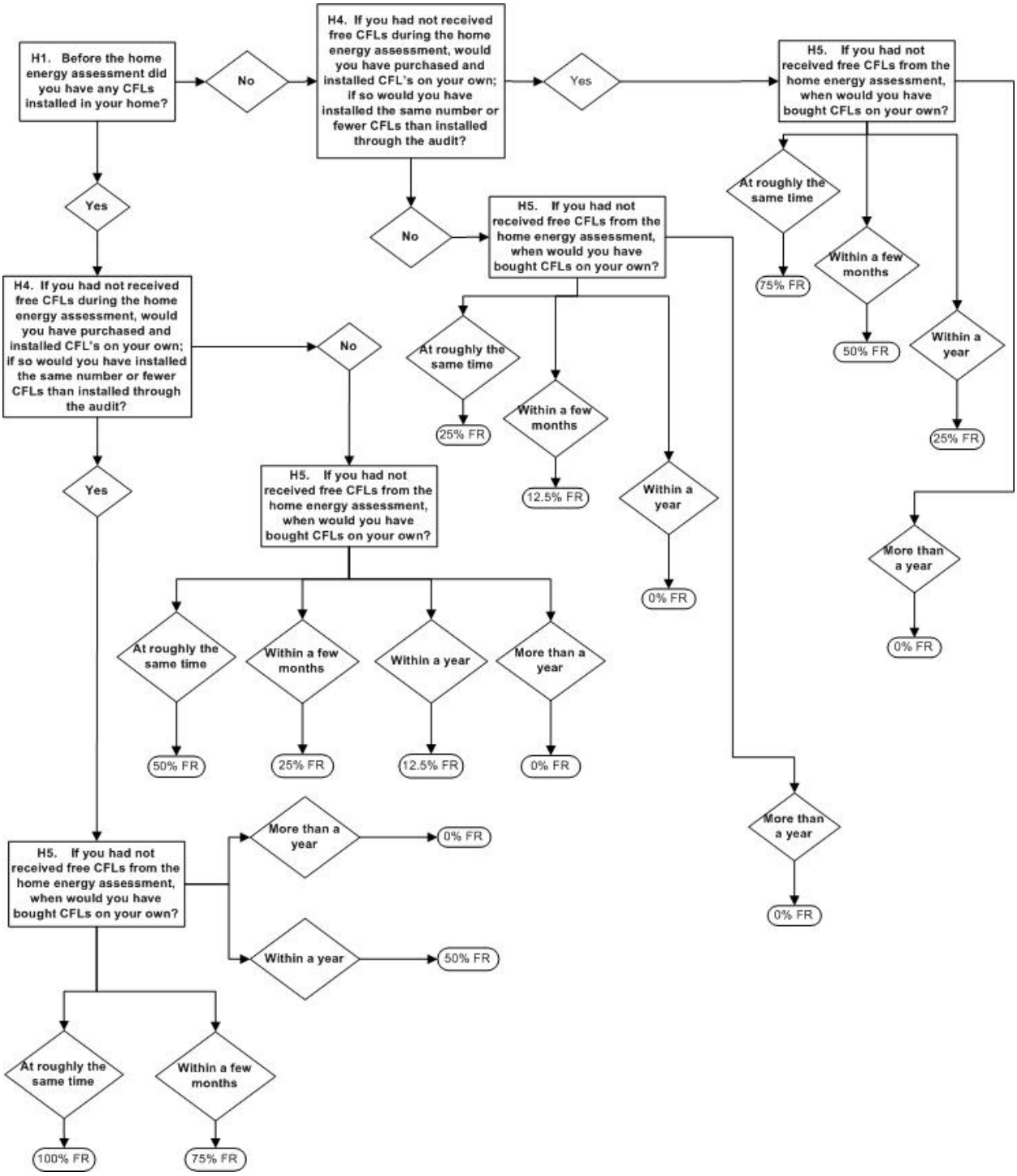


Diagram 2. Air Leak Sealing Direct Install Free-ridership Logic Model

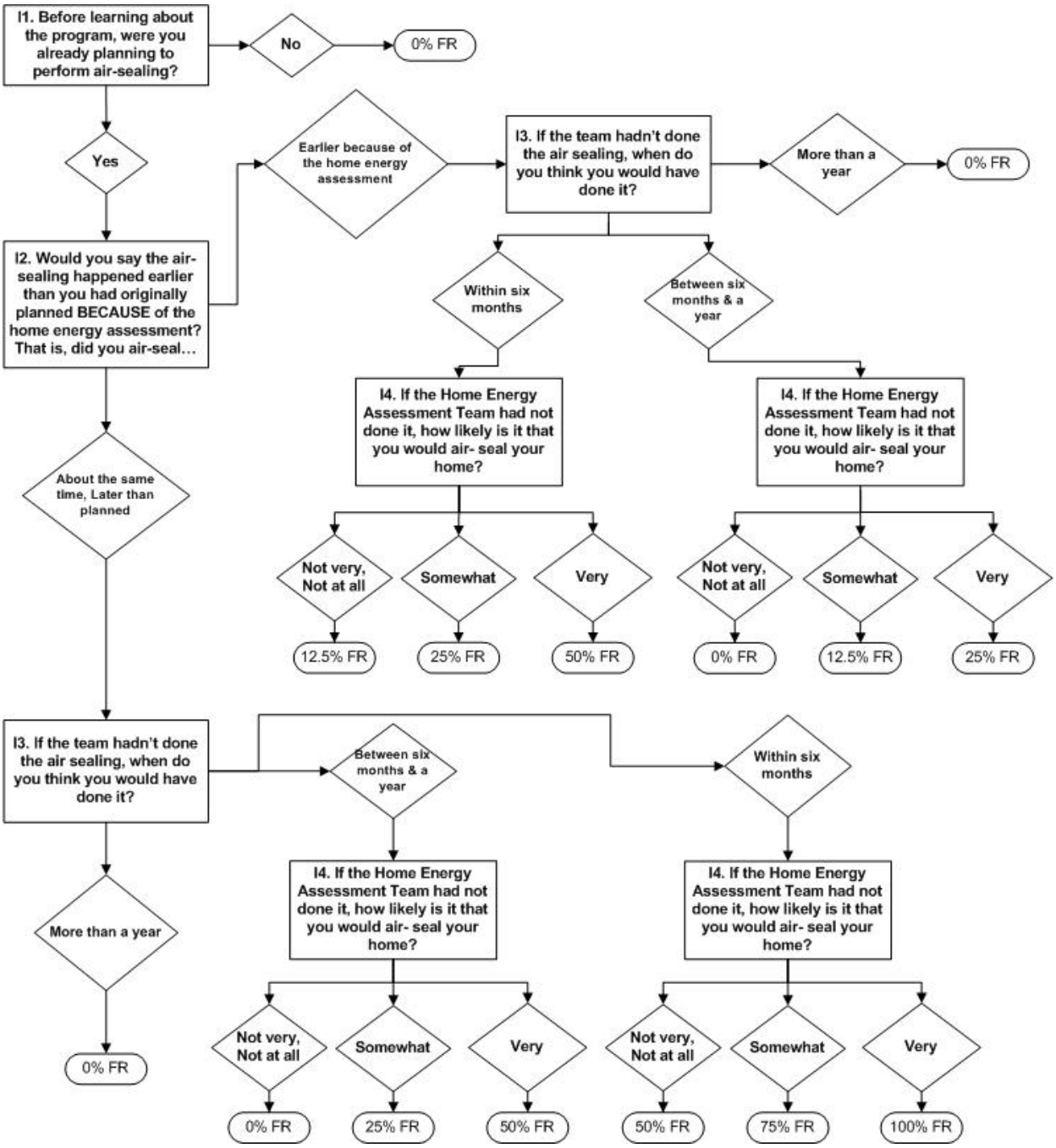


Diagram 3. Insulation Measures Direct Install Free-ridership Logic Model

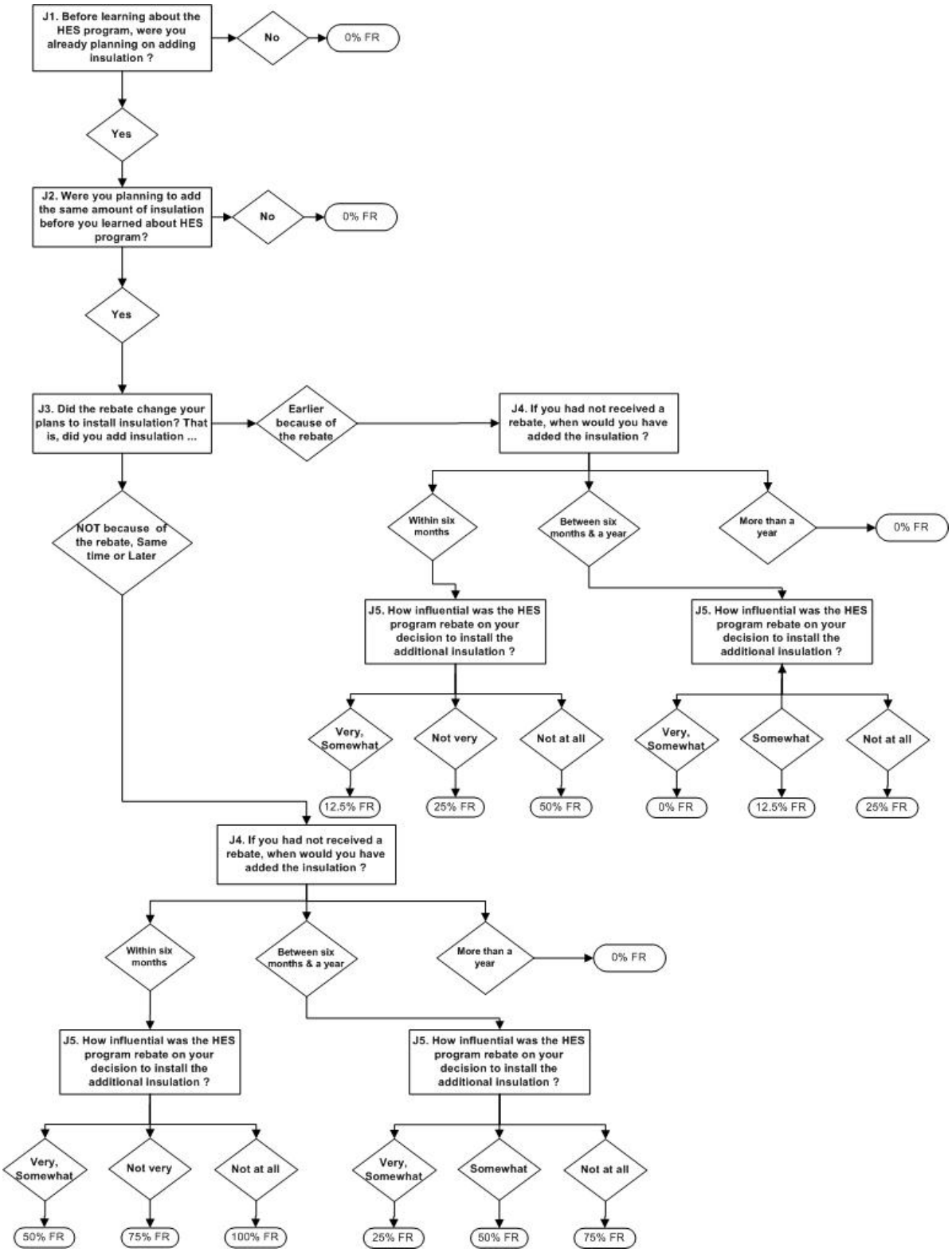
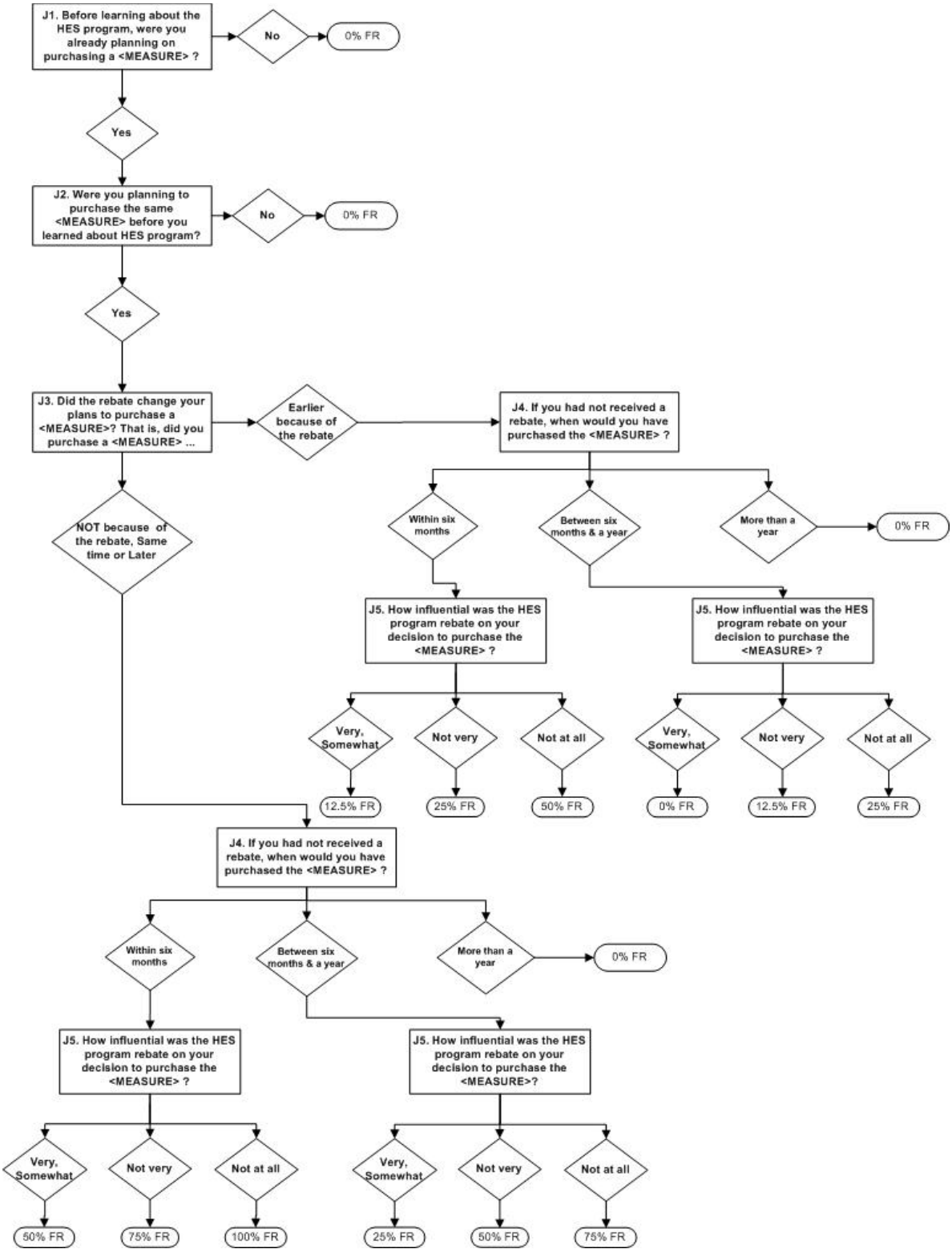


Diagram 4. Free-ridership Logic Model for Measures for which an Incentive was Offered: Heating Systems, Water Heaters, and Refrigerators



Converting Responses to Matrix Terminology

We independently evaluated each survey question's responses to assess the participants' overall free-ridership level for each question. We converted each survey response option into a value of Yes (indicative of free-ridership), No (not indicative of free-ridership), or Partial (partially indicative of free-ridership).

Table 10 lists the three CFL free-ridership survey questions, their corresponding response options, and the responses' converted values (in parentheses). We converted Don't know and Refused responses to Partial for the first two questions. For the third question, we defined two levels of partial free-ridership, determining that if a participant was unsure when they would have purchased the measure, they were unlikely to be a FR and should receive a lower free-ridership score, which is represented by a Partial2[8] matrix value. We followed the same methodology for both the electric participant and gas participant free-ridership analysis.

Table 10. Assignments of CFL Response Options into Matrix Terminology

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

Table 11 lists the four air sealing direct install free-ridership survey questions, their corresponding response options, and the responses' converted values (in parentheses). We converted Don't know and Refused responses to Partial for all four questions. We followed the same methodology for both the electric participant and gas participant free-ridership analysis.

[8] We assigned a Partial2 matrix value for the third question for Within a year, Don't Know, and Refused survey responses.

Table 11. Assignments of Air Sealing Direct Install Response Options into Matrix Terminology

Before learning about the HES Program, were you already planning to <MEASURE>?	Would you say it happened earlier than you had originally planned BECAUSE of the HES?	If the team hadn't installed air sealing, when do you think you would have installed it?	If the HES team had not installed air sealing, how likely is it that you would air-seal your home?
Yes (Yes)	Earlier because of the home energy assessment (No)	Within six months (Yes)	Very likely (Yes)
No (No)	Earlier than planned but NOT because of the home energy assessment (Yes)	Between six months and a year (Partial)	Somewhat likely (Partial)
Don't know (Partial)	About the same time as planned (Yes)	More than a year (No)	Not very likely (No)
Refused (Partial)	Later than planned (Yes)	Don't know (Partial)	Not at all likely (No)
	Don't know (Partial)	Refused (Partial)	Don't know (Partial)
	Refused (Partial)		Refused (Partial)

Table 12 lists the five free-ridership survey questions for insulation measures in which an incentive was offered, their corresponding response options, and the responses' converted values (in parentheses). We converted Don't know and Refused responses to Partial for all the questions. We followed the same methodology for both the electric participant and gas participant insulation free-ridership analysis.

Table 12. Assignments of Response Options into Matrix Terminology for Insulation Measures for which an Incentive was Offered

Before learning about the HES Program, were you already planning on installing insulation?	Were you planning to add the same amount of insulation before you learned about HES Program?	Did the incentive change your plans to install insulation? That is, did you install insulation...	If you had not received an incentive, when would you have installed insulation? Would you have installed insulation…	How influential was the HES Program incentive on your decision to install the insulation?
Yes (Yes)	Yes (Yes)	Because of the incentive (No)	Within six months (Yes)	Very influential (No)
No (No)	No (No)	Not because of the incentive (Yes)	Between six months and a year later (Partial)	Somewhat influential (No)
Don't know (Partial)	Don't know (Partial)	Don't know (Partial)	More than a year later (No)	Not very influential (Partial)
Refused (Partial)	Refused (Partial)	Refused (Partial)	Don't know (Partial)	Not at all influential (Yes)
			Refused (Partial)	Don't know (Partial)
				Refused (Partial)

Table 13 lists the five free-ridership survey questions for all the remaining measures for which an incentive was offered, their corresponding response options, and the responses' converted values (in parentheses). We converted Don't know and Refused responses to Partial for all the questions. We followed this methodology only for electric participants that received an incentive for measures that fall into the category of a heating system, refrigerator, or water heater.

Table 13. Assignments of the Response Options into Matrix Terminology for Remaining Measures for which an Incentive was Offered

Before learning about the HES Program, were you already planning on installing a <MEASURE>?	Were you planning to purchase a <MEASURE> with the same level of energy efficiency before you learned about the HES Program?	Did the incentive change your plans to install a <MEASURE>? That is, did you add a <MEASURE>?	If you had not received an incentive, when would you have purchased a <MEASURE>?	How influential was the HES Program incentive on your decision to install the <MEASURE>?
Yes (Yes)	Yes (Yes)	Because of the incentive (No)	Within six months (Yes)	Very influential (No)
No (No)	No (No)	Not because of the incentive (Yes)	Between six months and a year later (Partial)	Somewhat influential (No)
Don't know (Partial)	Don't know (Partial)	Don't know (Partial)	More than a year later (No)	Not very influential (Partial)
Refused (Partial)	Refused (Partial)	Refused (Partial)	Don't know (Partial)	Not at all influential (Yes)
			Refused (Partial)	Don't know (Partial)
				Refused (Partial)

Participant Free-ridership Scoring

After converting survey responses into matrix terminology, we created a free-ridership matrix for assigning the combination of each participant's responses with a free-ridership score. To create the matrix, we determined every combination of possible responses to the survey questions, and then assigned a free-ridership score of 0% to 100% to each combination. These matrices are provided as tables in Appendix B and are shown in the logic model diagrams in this appendix.

Free-ridership Error Bounds

To quantify self-report error bounds, we calculated error bounds at the 90% confidence level for each measure category. We found that virtually all measure-level free-ridership estimates fell within ±10% absolute precision, indicating that the program-level free-ridership estimates are consistent with industry standards.

We calculated absolute precision for the free-ridership estimates as follows:

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

Where:

1.645 = The multiplier used to obtain a 90% confidence interval

SD = The standard deviation of the mean free-ridership estimate

n = The total sample size

Measure-level confidence bounds are shown in Appendix B

Participant Spillover Methodology

We measured PS by asking participating customers if they decided to install other energy-efficiency measures after participating in the program. To tie these purported actions to their participation in the HES 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 the following three primary questions:

1. Since participating in the program, has the participant installed additional energy-efficient equipment for which they did not receive an incentive through a PA program?
2. What additional energy-efficient equipment was installed (and what quantity)?
3. How influential was the program in the participant's decision to install additional energy-efficient equipment in their home?

Using a process similar to estimating free-ridership, we determined PS by gauging the program's relative influence on their decision to pursue these additional energy saving measures.

If a respondent purchased the measure after participating in the HES Program, and they rated the program as highly influential in their decision to purchase the additional measure, we fully attributed their additional measure to PS. If a respondent rated the HES Program as somewhat influential, not very influential, or not at all influential on their additional purchase, we dropped their measure(s) from the spillover analysis.

We included responses to the CFL, air sealing, insulation, and refrigerator spillover measures that were not dropped in the Participant Self Report Spillover Analysis section of Appendix B.

Table 14 shows the methodology we used for estimating the customer self-report, measure-specific spillover rates for the HES Program.

Table 14. Self-Report Participant Spillover Estimation Methodology

Variable	Source / Calculation
(N) Participants	Program tracking databases
(n) Surveyed Participants	Participant survey data
(A) <MEASURE> Spillover Participants	Participant survey data
(B) Percent of Surveyed Participants that are <MEASURE> Spillover Participants	(A) ÷ (n)
(C) Estimated <MEASURE> Spillover Respondents for Participant Population	(B) * (N)
(D) Participant Population <MEASURE> Participants	Program tracking databases
(E) <MEASURE> Spillover Rate	(C)÷ (D)
Absolute Precision*	1.645 × SQRT (B - (1 - B) / n) × (N / D)

* 1.645 represents the z-score for the 90% confidence interval.

Spillover Error Bounds

To quantify self-report spillover error bounds, we calculated absolute precision estimates at the 90% confidence level for each spillover measure category. To obtain precision estimates for CFL, air sealing, insulation, and refrigerator spillover, we calculated the standard error of the spillover scores. Our 90% confidence interval is the standard error of the proportion of all participants multiplied by 1.645[9] and then multiplied by the total number of surveyed participants divided by the participant population for a given measure. Measure-level confidence bounds are shown in Appendix B.

Non-participant Spillover Methodology

The Evaluation Team estimated self-report NPS for insulation, air sealing, and CFL program measures. We asked non-participants if they had insulated their home, added air sealing, or installed CFLs within the past two years. For each of these measures a respondent mentioned installing, we asked if they learned about the HES Program before, after, or at the same time as their purchase.

We did not attribute respondents to NPS who said they learned about the program after they purchased the measure. For respondents who said they learned about the program at the same time or before purchasing the measure, we asked an additional question about why they did not apply for an incentive through the HES Program. We did not attribute the respondents to NPS if they gave one of the following reasons for not applying for an incentive:

- Their measure did not qualify for an incentive
- They actually had received a Mass Save incentive
- They were not aware of the HES Program at the time of the measure purchase (contrary to what they said before)

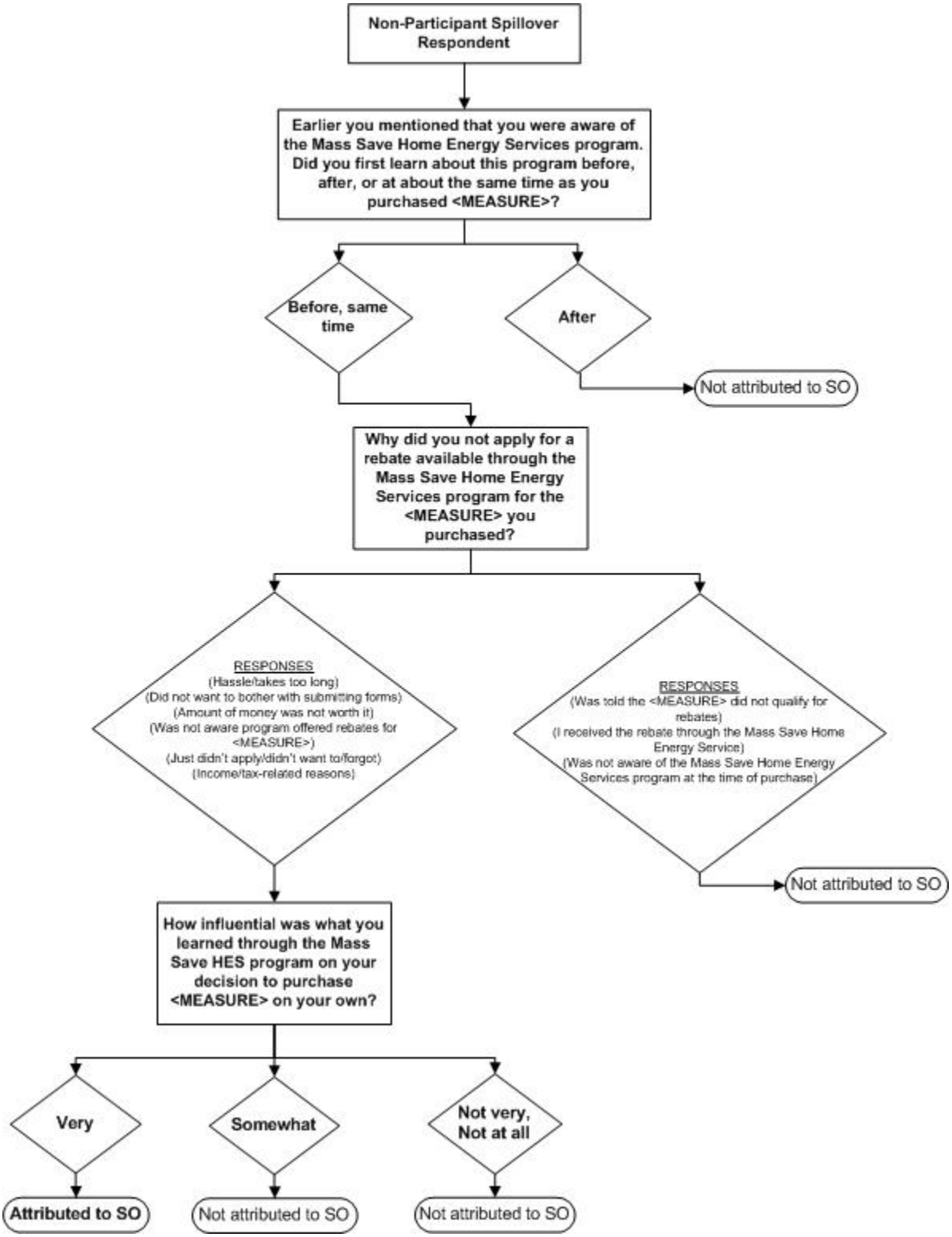
[9] 1.645 represents the z-score for the 90% confidence interval.

We asked respondents whether they did not apply for a program incentive due to one of the following reasons:

- It was a hassle or it takes too long
- They did not want to bother submitting the forms
- The amount of money was not worth it
- They were not aware that the program offered incentives
- Just did not apply/did not want to apply/forgot to apply
- Income/tax-related reasons

We also asked respondents how influential the information they learned through the HES Program was on their decision to purchase the measure. If a respondent said what they learned through the HES Program was very influential on their purchasing decision, we attributed the measures they installed to program NPS. If they said the HES Program information was somewhat, not very, or not at all influential, we did not attribute the measures they installed to NPS. Diagram 5 illustrates the methodology we applied to determine NPS actions, as it contains the logic flow for this analysis approach.

Diagram 5. Non-participant Spillover Logic Model



Appendix B. Measure-Specific Participant Self-Report Free-ridership and Spillover Results

Free-ridership

After conducting participant surveys, we derived each participant's free-ridership score by translating their responses into a matrix value, and then using a rules-based calculation to obtain the final score. This appendix presents all the combinations of survey responses for each program category, and the scores we assigned to each combination. The figures throughout this appendix show that participant responses rarely reflected each potential combination, but tended to group around a subset of common patterns. We calculated free-ridership scores, confidence intervals, and precision estimates for each program category based on the distribution of scores within the matrix.

CFL Free-ridership Analysis

Table 15 shows the results of free-ridership calculations for surveyed CFL program participants. The following sections outline our in-depth free-ridership analysis for each participant fuel type.

Table 15. CFL Free-ridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	567	0.28 (± 0.02)	0.30	0.26
Gas	386	0.31 (± 0.03)	0.34	0.28

Electric Participant CFL Free-ridership Results

Table 16 shows the unique response combinations from the electric CFL participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 16. Electric CFL Participant Free-ridership Results

Before the HES, did you have any CFLs installed in your home?	If you had not received free CFLs during the HES, would you have purchased and installed CFLs on your own, and if so, would you have installed the same number or fewer CFLs than installed through the audit?	If you had not received free CFLs from the HES, would you have bought CFLs on your own, and if so, when?	Free-ridership Score	Frequency
Yes	Yes	Yes	100%	35
Yes	Yes	Partial1*	75%	38
Yes	Yes	Partial2**	50%	44
Yes	Yes	No	0%	15
Yes	Partial	Yes	75%	13
Yes	Partial	Partial1	50%	51
Yes	Partial	Partial2	25%	88
Yes	Partial	No	0%	20
Yes	No	No	0%	121
No	Yes	Yes	75%	3
No	Yes	Partial1	50%	3
No	Yes	Partial2	25%	10
No	Yes	No	0%	2
No	Partial	Yes	50%	2
No	Partial	Partial1	25%	17
No	Partial	Partial2	12.5%	19
No	Partial	No	0%	1
No	No	No	0%	82
Partial	No	No	0%	1
Partial	Partial	Partial1	12.5%	1
Partial	Partial	No	0%	1

* We assigned a Partial1 matrix value to the third question for the survey response: Within a few months.

** We assigned a Partial2 matrix value for Within a year, Don't know, and Refused survey responses.

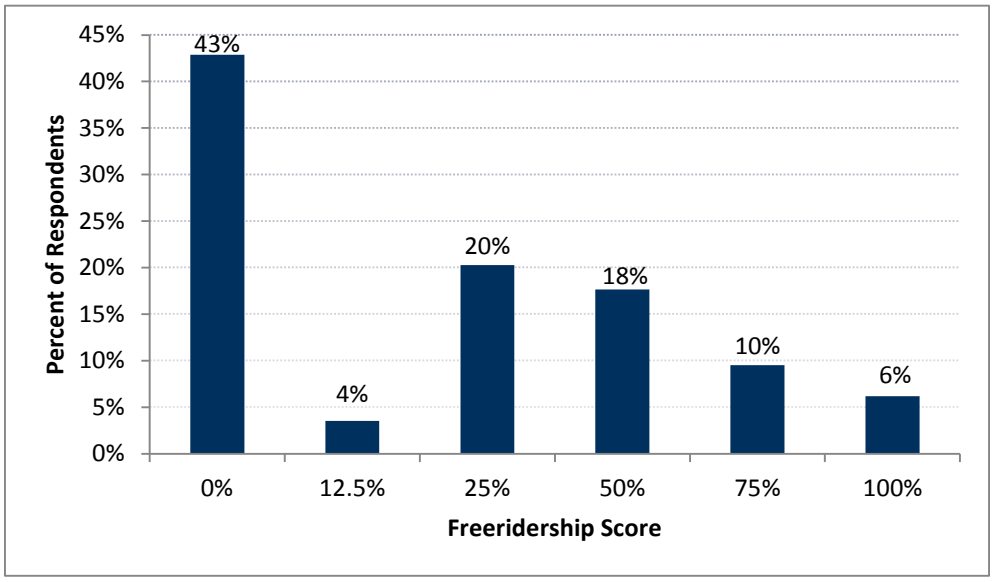
Two patterns appeared in the electric CFL respondents' answers to the free-ridership questions:

1. First, 117 respondents (21%) 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 they received through the assessment. Thirty-five of the 117 (30%) would have bought the CFLs at the same time and were scored as 100% FR. Thirty-eight of the 117 (32%) would have bought the CFLs within a few months and were scored as 75% FR. The final 44 of the 117 (38%) would have bought the CFLs within a year and were scored as 50% FR.
2. Second, 243 respondents (43%) would not have installed any CFLs on their own within the next year, and were scored as 0% FR.

Figure 3 shows the distribution of surveyed electric CFL participants by the free-ridership score assigned to each. Approximately 43% of CFL survey respondents indicated no free-ridership.

Additionally, 33% of respondents were considered 50% FR or higher, while low levels of free-ridership (12.5% and 25%) were observed for 24% of respondents.

Figure 3. Distribution of Electric CFL Participants' Free-ridership Scores



Gas Participant CFL Free-ridership Results

Table 17 shows the unique response combinations from the gas CFL participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 17. Gas CFL Participant Free-ridership Results

Before the HES, did you have any CFLs installed in your home?	If you had not received free CFLs during the HES, would you have purchased and installed CFL's on your own, and if so, would you have installed the same number or fewer CFLs than installed through the audit?	If you had not received free CFLs from the HES, would you have bought CFLs on your own, and if so, when?	Free-ridership Score	Frequency
Yes	Yes	Yes	100%	29
Yes	Yes	Partial1*	75%	39
Yes	Yes	Partial2**	50%	26
Yes	Yes	No	0%	7
Yes	Partial	Yes	75%	8
Yes	Partial	Partial1	50%	37
Yes	Partial	Partial2	25%	40
Yes	Partial	No	0%	17
Yes	No	No	0%	77
No	Yes	Yes	75%	5
No	Yes	Partial1	50%	5
No	Yes	Partial2	25%	5
No	Yes	No	0%	1
No	Partial	Yes	50%	3
No	Partial	Partial1	25%	9
No	Partial	Partial2	12.5%	8
No	Partial	No	0%	3
No	No	No	0%	65
Partial	No	No	0%	1
Partial	Yes	Partial2	25%	1

* We assigned a Partial1 matrix value to the third question for the survey response: Within a few months.

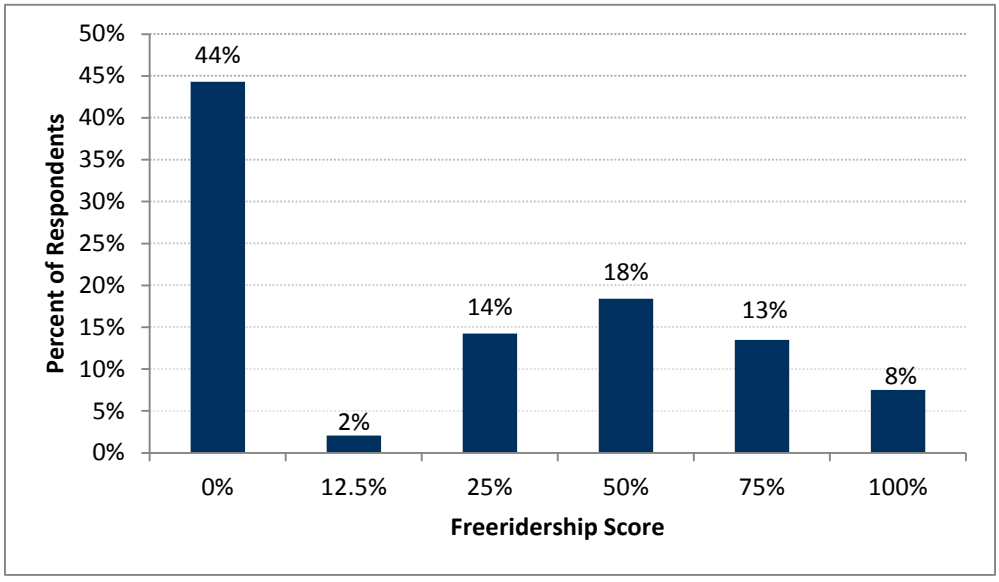
** We assigned a Partial2 matrix value for Within a year, Don't know, and Refused survey responses.

Three patterns appeared in the gas CFL respondents' answers to the free-ridership questions:

1. First, 94 respondents (24%) 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 they received through the assessment. Twenty-nine of the 94 (31%) would have bought the CFLs at the same time and were scored as 100% FR. Thirty-nine of the 94 (41%) would have bought the CFLs within a few months and were scored as 75% FR. The final 26 of the 94 (28%) would have bought the CFLs within a year and were scored as 50% FR.
2. Second, 85 respondents (22%) had CFLs installed in their home before the home energy assessment, would have installed CFLs on their own within the next year (but would have installed fewer CFLs than were installed through the audit), and would have bought the additional CFLs within at least a year. Eight of the 85 (9%) would have bought CFLs at the same time and were scored as 75% FR. Thirty-seven of the 85 (44%) would have bought the CFLs within the next few months and were scored as 50% FR. Forty of the 85 (47%) would have bought the CFLs within the next year and were scored as 25% FR.
3. Finally, 171 respondents (44%) would not have installed any CFLs on their own within the next year, and were scored as 0% FR.

Figure 4 shows the distribution of surveyed gas CFL participants by the free-ridership score assigned to each. Approximately 44% of CFL survey respondents indicated no free-ridership. Additionally, 39% of respondents were considered 50% FR or higher, while low levels of free-ridership (12.5% and 25%) were observed for 16% of respondents.

Figure 4. Distribution of Gas CFL Participants' Free-ridership Scores



Air Sealing Free-ridership Analysis

Table 18 shows the results of free-ridership calculations for surveyed air sealing program participants. The following sections outline our in-depth free-ridership analysis for each participant fuel type.

Table 18. Air Sealing Free-ridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	155	0.06 (± 0.03)	0.09	0.03
Gas	102	0.11 (± 0.04)	0.15	0.07

Electric Participant Air Sealing Free-ridership Results

Table 19 shows the unique response combinations from the electric air sealing participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 19. Electric Air Sealing Participant Free-ridership Results

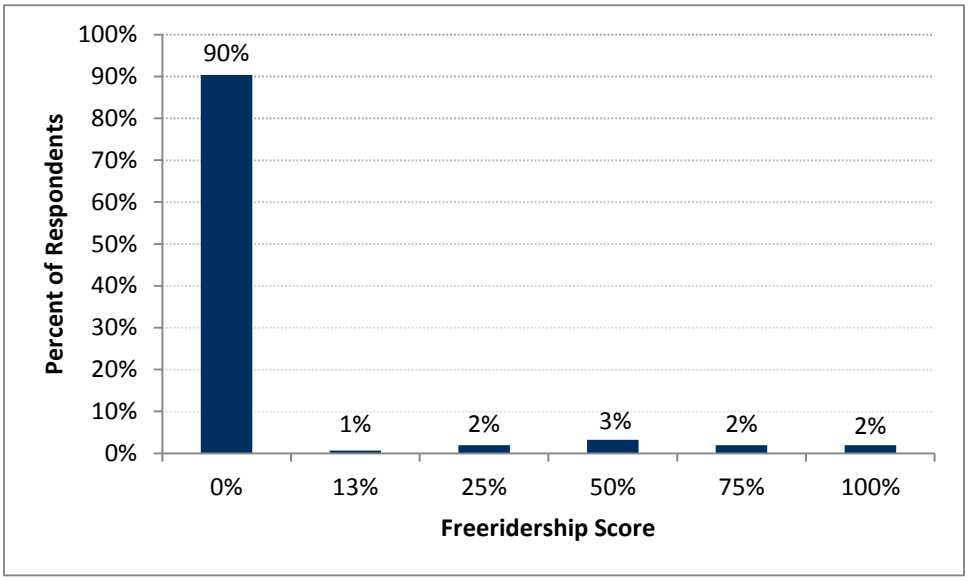
Before learning about the program, were you already planning to perform air-sealing?	Would you say the air-sealing happened earlier than you had originally planned BECAUSE of the HES?	If the team had not conducted the air sealing, when do you think you would have done it?	If the HES team had not conducted air sealing, how likely is it that you would air seal your home?	Free-ridership Score	Frequency
Yes	Partial	Partial	Yes	50%	2
Yes	No	Yes	Yes	50%	1
Yes	No	Yes	Partial	25%	2
Yes	No	Partial	Yes	25%	1
Yes	No	Partial	No	0%	1
Yes	No	No	Yes	12.5%	1
Yes	No	No	Partial	0%	3
Yes	No	No	No	0%	2
Yes	Yes	x	Yes	100%	3
Yes	Yes	x	Partial	75%	3
Yes	Yes	x	No	50%	2
No	x	x	x	0%	132
Partial	x	x	x	0%	2

Two patterns appeared in the electric air sealing respondents' answers to the free-ridership questions:

1. First, 132 respondents (85%) were not planning on air sealing before learning about the HES Program and were scored as 0% FR.
2. In total, 15 respondents (10%) received a free-ridership score above 0%, while 140 respondents (90%) were scored as 0% FR.

Figure 5 shows the distribution of surveyed electric air sealing participants by the free-ridership score assigned to each. Approximately 90% of air sealing survey respondents indicated no free-ridership. Additionally, 7% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for almost 3% of respondents.

Figure 5. Distribution of Electric Air Sealing Participants' Free-ridership Scores



Gas Participant Air Sealing Free-ridership Results

Table 20 shows the unique response combinations from the gas air sealing participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 20. Gas Air Sealing Participant Free-ridership Results

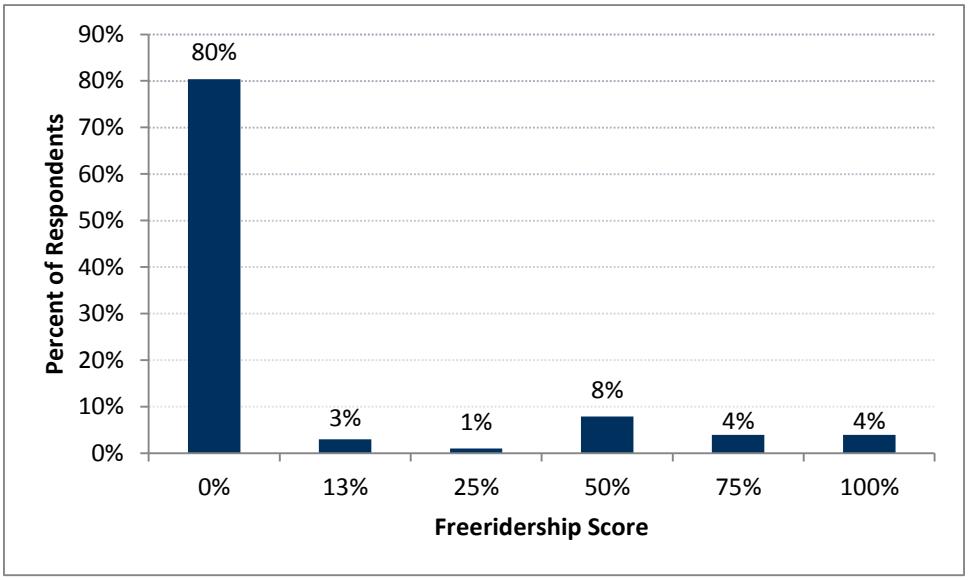
Before learning about the program, were you already planning to perform air-sealing?	Would you say the air-sealing happened earlier than you had originally planned BECAUSE of the HES?	If the team had not conducted the air sealing, when do you think you would have done it?	If the HES team had conducted air sealing, how likely is it that you would air seal your home?	Free-ridership Score	Frequency
Yes	Partial	Yes	Yes	75%	1
Yes	Partial	Partial	Yes	50%	2
Yes	Partial	No	No	0%	1
Yes	No	Yes	Yes	50%	2
Yes	No	Partial	Yes	25%	1
Yes	No	Partial	Partial	12.5%	2
Yes	No	Partial	No	0%	1
Yes	No	No	Yes	12.5%	1
Yes	No	No	Partial	0%	1
Yes	No	No	No	0%	3
Yes	Yes	x	Yes	100%	4
Yes	Yes	x	Partial	75%	3
Yes	Yes	x	No	50%	4
No	x	x	x	0%	76

Two patterns appeared in the gas air sealing respondents' answers to the free-ridership questions:

1. First, 76 respondents (75%) were not planning on air sealing before learning about the HES Program and were scored as 0% free-riders.
2. In total, 20 respondents (20%) received a free-ridership score above 0%, while 82 respondents (80%) were scored as 0% free-riders.

Figure 6 shows the distribution of surveyed gas air sealing participants by the free-ridership score assigned to each. Approximately 80% of air sealing survey respondents indicated no free-ridership. Additionally, almost 16% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for 4% of respondents.

Figure 6. Distribution of Gas Participant Air Sealing Free-ridership Scores



Insulation Free-ridership Analysis

Table 21 shows the results of free-ridership calculations for surveyed insulation program participants. The following sections outline our in-depth free-ridership analysis for each participant fuel type.

Table 21. Insulation Free-ridership Results

Fuel	Responses	FR Score	Upper Bound	Lower Bound
Electric	73	0.04 (± 0.03)	0.07	0.01
Gas	114	0.04 (± 0.02)	0.06	0.02

Electric Participant Insulation Free-ridership Results

Table 22 shows the unique response combinations from the electric insulation participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 22. Electric Insulation Participant Free-ridership Results

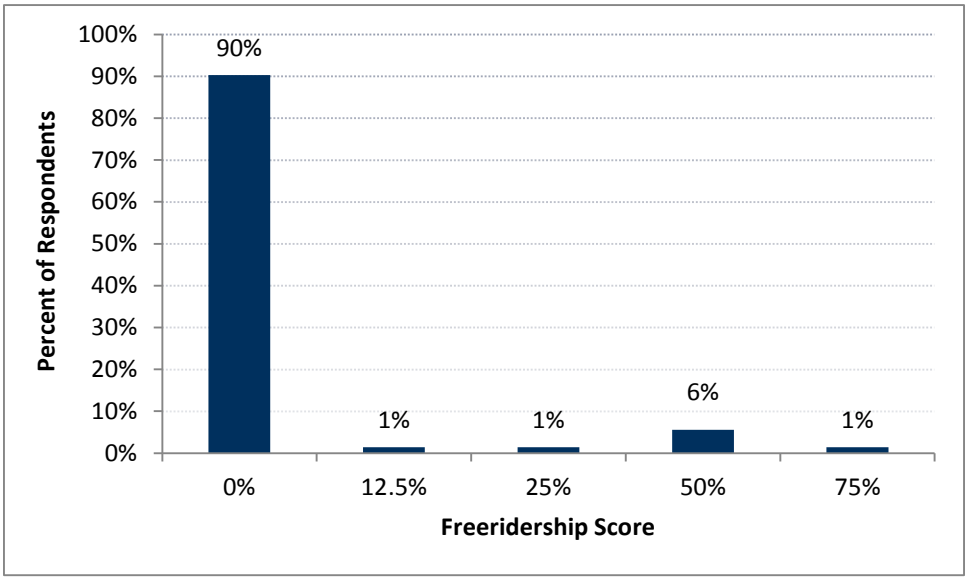
Before learning about the HES Program, were you already planning on installing insulation?	Were you planning to add the same amount of insulation before you learned about HES Program?	Did the incentive change your plans to install insulation ?	If you had not received an incentive, when would you have added the insulation?	How influential was the HES Program incentive on your decision to install the insulation?	Free-ridership Score	Frequency
Yes	Yes	Yes	Yes	Partial	75%	1
Yes	Yes	Yes	Yes	No	50%	4
Yes	Yes	Partial	Yes	No	25%	1
Yes	Yes	No	Yes	No	12.50%	1
Yes	Yes	No	Partial	No	0%	2
Yes	Yes	No	No	x	0%	2
Yes	No	x	x	x	0%	15
No	x	x	x	x	0%	47

Two patterns appeared in the electric insulation respondents' answers to the free-ridership questions:

1. First, 47 respondents (64%) were not planning on installing insulation before learning about the HES Program and were scored as 0% free-riders.
2. In total, seven respondents (10%) received a free-ridership score above 0%, while 66 (90%) were scored as 0% free-riders.

Figure 7 shows the distribution of surveyed electric insulation participants by the free-ridership score assigned to each. Approximately 90% of insulation survey respondents indicated no free-ridership. Additionally, 7% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for 3% of respondents.

Figure 7. Distribution of Electric Insulation Participants' Free-ridership Scores



Gas Participant Insulation Free-ridership Results

Table 23 shows the unique response combinations from the gas insulation participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 23. Gas Insulation Participant Free-ridership Results

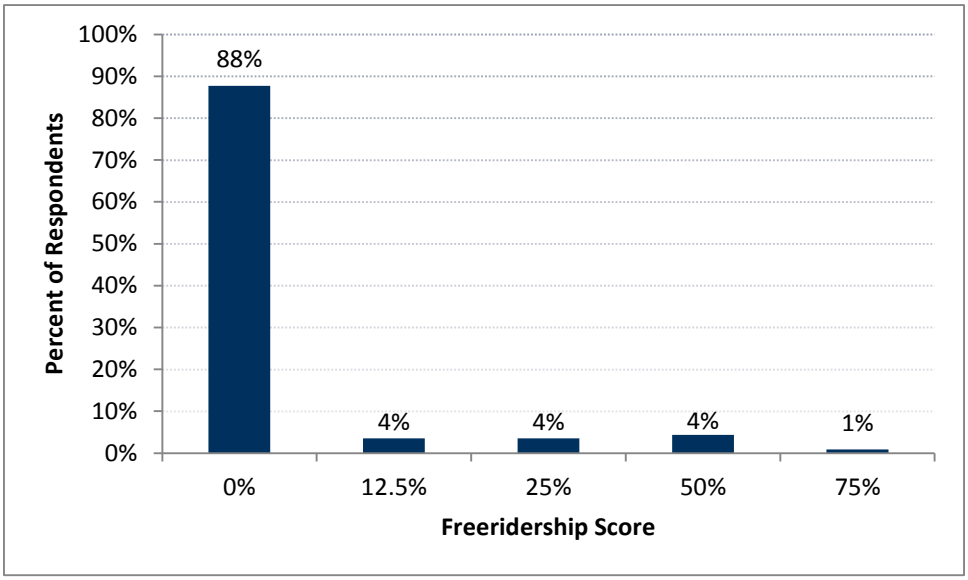
Before learning about the HES Program, were you already planning on installing insulation?	Were you planning to add the same amount of insulation before you learned about HES Program?	Did the incentive change your plans to install insulation?	If you had not received an incentive, when would you have added the insulation?	How influential was the HES Program incentive on your decision to install the insulation?	Free-ridership Score	Frequency
Yes	Yes	Yes	Yes	Partial	75%	1
Yes	Yes	Yes	Yes	No	50%	5
Yes	Yes	Partial	Partial	No	12.5%	1
Yes	Yes	Partial	x	No	12.5%	1
Yes	Yes	No	Yes	No	12.5%	2
Yes	Yes	No	Partial	Yes	25%	1
Yes	Yes	No	Partial	No	0%	1
Yes	Yes	No	No	x	0%	6
Yes	Partial	Yes	Yes	No	25%	3
Yes	Partial	Partial	Partial	No	0%	1
Yes	Partial	No	Yes	No	0%	1
Yes	Partial	No	Partial	No	0%	1
Yes	Partial	No	No	x	0%	1
Yes	No	x	x	x	0%	16
No	x	x	x	x	0%	73

Three patterns appeared in the gas insulation respondents' answers to the free-ridership questions:

1. First, 73 respondents (64%) were not planning on buying insulation before learning about the HES Program and were scored as 0% free-riders.
2. Seven respondents (6%) would not have purchased the insulation within one year and were scored as 0% free-riders.
3. In total, 14 respondents (12%) received a free-ridership score above 0%, while 100 respondents (88%) were scored as 0% free-riders.

Figure 8 shows the distribution of surveyed gas insulation participants by the free-ridership score assigned to each. Approximately 88% of insulation survey respondents indicated no free-ridership. Additionally, 5% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for 7% of respondents.

Figure 8. Distribution of Gas Insulation Participants' Free-ridership Scores



Free-ridership Analysis for Additional Measures for which an Incentive was Offered

Table 24 shows the results of free-ridership calculations for additional measures installed by surveyed program participants (excluding the insulation participants addressed above). The following sections outline our in-depth free-ridership analysis for each measure. Due to the small sample sizes, we analyzed the results for heating systems, water heaters, and refrigerators overall, not by the participants' fuel type (electric vs. gas).

Table 24. Free-ridership Results for Other Measures for which an Incentive was Offered

Measure	Responses	FR Score	Upper Bound	Lower Bound
Heating System	45	0.24 (± 0.08)	0.32	0.16
Water Heater	35	0.29 (± 0.10)	0.39	0.19
Refrigerator	17	0.14 (± 0.10)	0.24	0.04

Heating System Participant Free-ridership Results

Table 25 shows the unique response combinations from the heating system participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 25. Heating System Participant Free-ridership Results

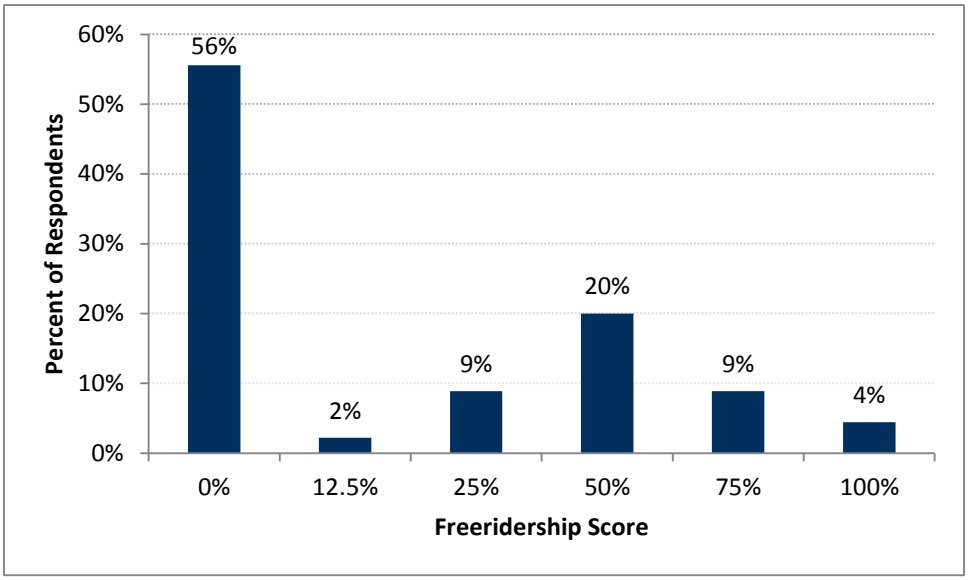
Before learning about the HES Program, were you already planning on installing a heating system?	Were you planning to purchase a heating system with the same level of efficiency before you learned about HES Program?	Did the incentive change your plans to install a heating system?	If you had not received an incentive, when would you have installed a heating system?	How influential was the HES Program incentive on your decision to install a heating system?	Free-ridership Score	Frequency
Yes	Yes	Yes	Yes	Yes	100%	2
Yes	Yes	Yes	Yes	Partial	75%	2
Yes	Yes	Yes	Yes	No	50%	7
Yes	Yes	Partial	Yes	Yes	75%	1
Yes	Yes	Partial	Yes	No	25%	1
Yes	Yes	No	Yes	Yes	50%	1
Yes	Yes	No	Yes	No	12.5%	1
Yes	Yes	No	Partial	No	0%	3
Yes	Yes	No	No	x	0%	5
Yes	Partial	Yes	Yes	Yes	75%	1
Yes	Partial	Yes	Yes	No	25%	3
Yes	Partial	Partial	Yes	Yes	50%	1
Yes	Partial	No	Partial	No	0%	1
Yes	No	x	x	x	0%	10
No	x	x	x	x	0%	6

Four patterns appeared in the heating system respondents' answers to the free-ridership questions:

1. Six respondents (13%) were not planning on buying a heating system before learning about the HES Program and were scored as 0% free-riders.
2. Five respondents (11%) were not planning on purchasing a heating system within one year before learning about the HES Program and were scored as 0% free-riders.
3. Ten respondents (22%) were not planning on purchasing a heating system with the same level of efficiency before learning about the HES Program and were scored as 0% free-riders.
4. In total, 20 respondents (44%) received a free-ridership score above 0%, while25 respondents (56%) were scored as 0% free-riders.

Figure 9 shows the distribution of surveyed heating system participants by the free-ridership score assigned to each. Approximately 56% of heating system survey respondents indicated no free-ridership. Additionally, 33% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for 11% of respondents.

Figure 9. Distribution of Electric Participant Heating System Free-ridership Scores



Water Heater Participant Free-ridership Results

Table 26 shows the unique response combinations from the water heater participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 26. Water Heater Participant Free-ridership Results

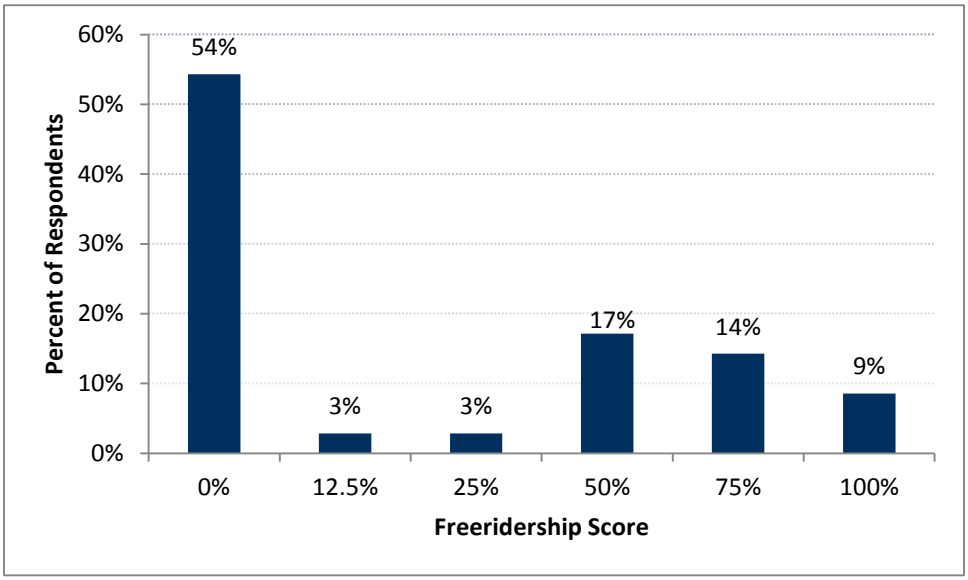
Before learning about the HES Program, were you already planning on installing a hot water heater?	Were you planning to purchase a hot water heater with the same level of energy efficiency before you learned about HES Program?	Did the incentive change your plans to install a hot water heater?	If you had not received an incentive, when would you have installed a hot water heater?	How influential was the HES Program incentive on your decision to install the hot water heater?	Free-ridership Score	Frequency
Yes	Yes	Yes	Yes	Yes	100%	3
Yes	Yes	Yes	Yes	Partial	75%	3
Yes	Yes	Yes	Yes	No	50%	5
Yes	Yes	Partial	Yes	Yes	75%	1
Yes	Yes	Partial	Yes	No	25%	1
Yes	Yes	Partial	x	Yes	75%	1
Yes	Yes	No	Yes	No	12.5%	1
Yes	Yes	No	Partial	No	0%	3
Yes	Yes	No	No	x	0%	1
Yes	Partial	Yes	Yes	Partial	50%	1
Yes	No	x	x	x	0%	6
No	x	x	x	x	0%	9

Three patterns appeared in the water heater respondents' answers to the free-ridership questions:

1. Nine respondents (26%) were not planning on buying a water heater before learning about the HES Program and were scored as 0% free-riders.
2. Five respondents' (14%) answers to the survey battery indicated free-ridership for every question, except that they rated the HES Program incentive as being highly influential on their decision to purchase the water heater. These respondents were scored as 50% free-riders. Three respondents' (9%) answers to the survey battery indicated free-ridership for every question. These respondents were scored as 100% free-riders.
3. In total, 16 respondents (46%) received a free-ridership score above 0%, while 19 respondents (54%) were scored as 0% free-riders.

Figure 10 shows the distribution of surveyed water heater participants by the free-ridership score assigned to each. Approximately 54% of water heater survey respondents indicated no free-ridership. Additionally, 40% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5% and 25%) were observed for 6% of respondents.

Figure 10. Distribution of Electric Participant Water Heater Free-ridership Scores



Refrigerator Participant Free-ridership Results

Table 27 shows the unique response combinations from the refrigerator participants, the free-ridership score we assigned to each combination, and the number of responses for each combination.

Table 27. Refrigerator Participant Free-ridership Results

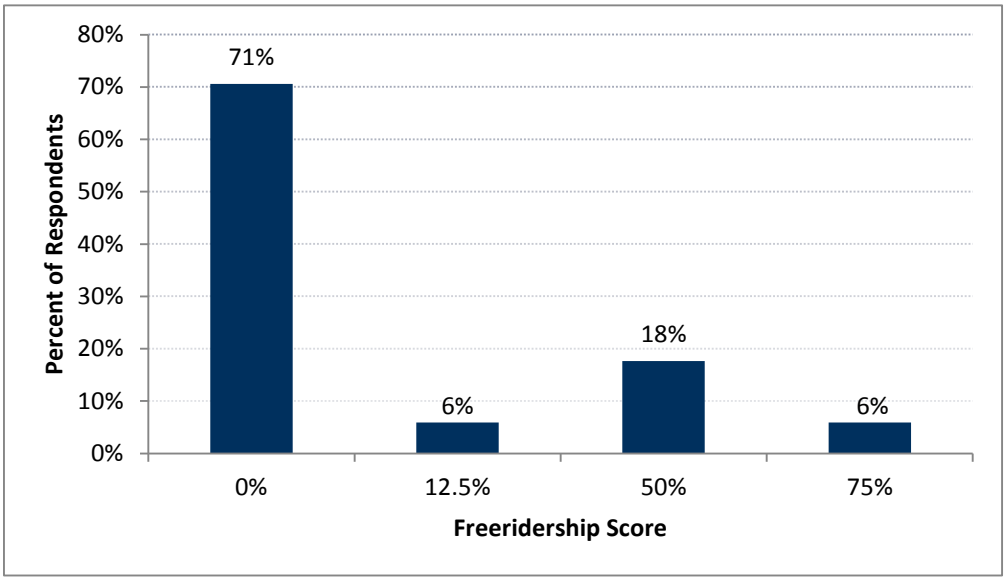
Before learning about the HES Program, were you already planning on installing a refrigerator?	Were you planning to purchase a refrigerator with the same level of energy efficiency before you learned about HES Program?	Did the incentive change your plans to install a refrigerator ?	If you had not received an incentive, when would you have installed a refrigerator?	How influential was the HES Program incentive on your decision to install a refrigerator?	Free-ridership Score	Frequency
Yes	Yes	Yes	Yes	Partial	75%	1
Yes	Yes	Yes	Yes	No	50%	3
Yes	Yes	Partial	No	x	0%	1
Yes	Yes	No	Yes	No	12.5%	1
Yes	No	x	x	x	0%	2
No	x	x	x	x	0%	9

Two patterns appeared in the refrigerator respondents' answers to the free-ridership questions:

1. Nine respondents (53%) were not planning on buying a refrigerator before learning about the HES Program and were scored as 0% free-riders.
2. In total, five respondents (29%) received a free-ridership score above 0%, while 12 respondents (71%) were scored as 0% free-riders.

Figure 11 shows the distribution of surveyed refrigerator participants by the free-ridership score assigned to each. Approximately 71% of refrigerator survey respondents indicated no free-ridership. Additionally, 24% of respondents were considered 50% free-riders or higher, while low levels of free-ridership (12.5%) were observed for about 6% of respondents.

Figure 11. Distribution of Electric Participant Refrigerator Free-ridership Scores



Participant Self Report Spillover Analysis

This section presents a detailed analysis of additional energy-efficient measures customers installed after participating in the HES Program. As mentioned in the Participant Spillover Methodology section, due to the uncertainty of the efficiency and type of measures, we only estimated self-report PS for CFLs, air sealing, and insulation. The Evaluation Team determined that spillover information obtained from the participant surveys was only detailed enough to accurately estimate spillover for these measures).

Spillover Results

Table 28 shows the spillover results for CFLs, air sealing, and insulation measures. The following sections outline our in-depth spillover analysis for each measure.

Table 28. CFLs, Air Sealing, Insulation, and Refrigerator Participant Spillover Results

Measure	Spillover Rate	Upper Bound	Lower Bound
CFL	0.025 (± 0.009)	0.034	0.016
Air Sealing	0.08 (± 0.025)	0.103	0.055
Insulation	0.20 (± 0.04)	0.24	0.16

CFL Spillover Results

If a respondent said their participation in the HES Program was highly influential on their additional CFL purchases, we attributed those purchases to program spillover. In total, 20.5 such survey respondents installed CFLs outside the program. Table 29 shows The Evaluation Team's calculation process for arriving at the 2.5% customer self-report spillover estimate.

Table 29. CFL Self Report Spillover Estimation

Variable	Value	Source / Calculation
(N) Participants	37,992	Program tracking databases
(n) Surveyed Participants	1,200	Participant survey data
(A) CFL Spillover Participants	20.5	Participant survey data
(B) Percent of Surveyed Participants that are CFL Spillover Participants	0.017	(A) ÷ (n)
(C) Estimated CFL Spillover Respondents from Participant Population	649	(B) * (N)
(D) Participant Population CFL Participants	26,064	Program tracking databases
(E) CFL Spillover Rate	0.0249	(C) ÷ (D)
Absolute Precision	0.009	1.645 * SQRT (B - (1 - B) / n) * (N / D)

* 1.645 represents the z-score for the 90% confidence interval.

Air Sealing Spillover Results

If a respondent said their participation in the HES Program was highly influential on their additional air sealing, we attributed that air sealing to program spillover. In total, 25.5 such survey respondents had air sealing performed outside the program. Table 30 shows The Evaluation Team's calculation process for arriving at the 8% customer self-report spillover estimate.

Table 30. Air Sealing Self Report Spillover Estimation

Variable	Value	Source / Calculation
(N) Participants	37,992	Program tracking databases
(n) Surveyed Participants	1,200	Participant survey data
(A) Air Sealing Spillover Participants	25.5	Participant survey data
(B) Percent of Surveyed Participants that are Air Sealing Spillover Participants	0.021	(A) ÷ (n)
(C) Estimated Air Sealing Spillover Respondents from Participant Population	807	(B) * (N)
(D) Participant Population Air Sealing Participants	10,348	Program tracking databases
(E) CFL Spillover Rate	0.08	(C) ÷ (D)
Absolute Precision	0.025	1.645 * SQRT (B - (1 - B) / n) * (N / D)

* 1.645 represents the z-score for the 90% confidence interval.

Insulation Spillover Results

If a respondent said their participation in the HES Program was highly influential on their additional insulation purchase, we attributed that insulation to program spillover. In total, 70 such survey respondents had insulation installed outside the program. Table 31 shows The Evaluation Team's calculation process for arriving at the 20% customer self-report spillover estimate.

Table 31. Insulation Self Report Spillover Estimation

Variable	Value	Source / Calculation
(N) Participants	37,992	Program tracking databases
(n) Surveyed Participants	1,200	Participant survey data
(A) Insulation Spillover Participants	70	Participant survey data
(B) Percent of Surveyed Participants that are Insulation Spillover Participants	0.058	(A) ÷ (n)
(C) Estimated Insulation Spillover Respondents from Participant Population	2216	(B) * (N)
(D) Participant Population Insulation Participants	10,932	Program tracking databases
(E) CFL Spillover Rate	0.20	(C) ÷ (D)
Absolute Precision	0.04	1.645 * SQRT (B - (1 - B) / n) * (N / D)

* 1.645 represents the z-score for the 90% confidence interval.

The Evaluation Team

Non-participant Spillover Results

The Evaluation Team estimated self-report NPS for insulation, air sealing, and CFL program measures. We asked non-participants if they had insulated their home, added air sealing, or installed CFLs within the past two years. For each of these measures a respondent mentioned installing, we asked if they learned about the HES Program before, after, or at the same time as their purchase.

We did not attribute respondents to spillover who said they learned about the program after they purchased the measure. We asked respondents who said they learned about the program at the same time or before purchasing the measure an additional question about why they did not apply for an incentive through the HES Program. We did not attribute the respondents to spillover if they gave one of the following reasons for not applying for an incentive:

- Their measure did not qualify for an incentive
- They actually had received a Mass Save incentive
- They were not aware of the HES Program at the time of the measure purchase (contrary to what they said before).

We asked respondents whether they did not apply for a program incentive due to one of the following reasons:

- It was a hassle or it takes too long
- They did not want to bother submitting the forms
- The amount of money was not worth it
- They were not aware that the program offered incentives
- Just did not apply/did not want to apply/forgot to apply
- Income/tax-related reasons

We also asked respondents how influential the information they learned through the HES Program was on their decision to purchase the measure. If a respondent said what they learned through the HES Program was very influential on their purchasing decision, we attributed the measures they installed to program NPS. If they said the HES Program information was somewhat, not very, or not at all influential, we did not attribute the measures they installed to NPS.

Table 32 shows the self-report NPS results for the HES Program.

Table 32. CFL, Insulation, and Air Sealing Non-participant Spillover Results

Measure	(A) Weighted Non-participant Spillover Mentions	(B) Non-participant Survey Sample (n)	(C) Non-participant Spillover (A ÷ B)	(D) Estimated Non-participant Population*	(E) Estimated # of Spillover Measures for Non-participant Population (C × D)**
CFLs	11.2	1,202	0.93%	1,490,000	13,891
Insulation	4.4	1,202	0.28%+[10]	700,000	1,960
Air Sealing	3.8	1,202	0.32%	1,250,000	3,991

* The Evaluation Team estimated the eligible non-participant population size using data from the 2010 American Community Survey (ACS) and from the 2009 Opinion Dynamics Corporation *Massachusetts Residential Appliance Saturation Survey* (RASS) available online at http://www.env.state.ma.us/dpu/docs/electric/09-64/12409nstrd2af.pdf.

** Differences are due to rounding of variable (C) Non-participant Spillover.

+ The non-participant survey asked for self-reported insulation installs over a two-year period. We annualized the survey results and corrected for differences in the in-program and out-of-program installation quantity/quality by multiplying the annual installation estimate from the survey by the ratio of out-of-program to in-program insulation costs.

[10] The non-participant survey asked for information about self-reported insulation installs over a two-year period. We annualized the survey results and corrected for differences in the in-program and out-of-program installation quantity/quality by multiplying the annual installation estimate from the survey by the ratio of out-of-program to in-program insulation costs.

Appendix C: Discrete Choice Results for Insulation

The Evaluation Team began the free-ridership and NPS estimation process by fitting a mixed logit model with the DC alternatives described in Figure 2 and the customer utility variables listed in Table 2. To determine the explanatory variables used in the final model, we compared several alternative model specifications in terms of Akaike's Information Criterion (AIC),[11] 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).

The fitted model's mean coefficient estimates are shown in Table 33. We used these parameters to estimate the knowable portion of each respondent's utility for each alternative, which in turn the model translated into the probability of selecting each alternative. As such, the nominal values of the parameters in a DC model are not easily interpreted. However, the sign of the parameter estimates provides useful information. For example, the sign on the Incentive x Alt2 parameter is positive, indicating that an increase in incentive amount increases the modeled probability that a respondent would choose to purchase insulation through the HES Program.[12]

Table 33. Final Model Parameter Estimates for Insulation

Model Term	Parameter Estimate	t Value
Age	0.0059	2.64
Motive_Comfort	0.5761	9.28
EE_Very_Knowledgeable	0.4669	6.89
Alt2	-2.6837	-16.02
Incentive x Alt2	0.0003	5.30
Home_Age x Alt2	-0.0049	-3.33
Gas_Heat x Alt2	-0.0295	-0.35
HES Influence x Ads x Alt2	0.3373	17.39
Alt3	-5.6849	-25.19
Gas_Heat x Alt3	4.0272	20.72
HES Influence x Ads x Alt3	-0.1596	-1.75
Non-participant Homeowner x Alt3	0.4719	8.11

Note: Alternative 2 indicates being purchased with a program incentive, and Alternative 3 indicates being purchased without a program incentive.

The alternative specific constants in the model specified above serve to calibrate the model-estimated probabilities for each alternative to those observed in the population. As shown in this section, we estimated that approximately 700,000 homes in Massachusetts would qualify or are effectively eligible for HES Program insulation. The population probabilities in Table 34 reflect

[11] AIC is a relative measure of a model's goodness of fit. Among a set of candidate models, the preferred model is the one that minimizes AIC.

[12] Our weighting methodology increases the apparent significance of the estimated coefficients in the final model by replicating observations. We ran a model with the same specification as Table 33 on an unweighted sample and noted that the signs, magnitude, and significance of the coefficients were similar to those shown in Table 33.

this population size. Approximately 1.4% of the 2011 qualified homes purchased insulation through the HES Program (approximately 10,900 HES Program insulation installations); while non-participant survey results indicate that a larger number of homes purchased insulation outside of the HES Program (approximately 7% per year).[13]

Table 34. Observed and Modeled Probabilities by Alternative - Insulation

Alternative	Observed Sample Probability	Modeled Probability	Population Probability
No Purchase	74%	74%	91.8%
Purchase Through HES Program	14%	14%	1.43%
Purchase Outside HES Program	12%	12%	6.74%

We adjusted the coefficients on the alternative specific constants in order to calibrate the model-estimated probabilities for each alternative to those of a statewide population, rather than to the observed sample.[14] Table 35 shows the adjusted alternative-specific coefficients that calibrated the modeled probabilities to the population probabilities shown in Table 34.

Table 35. Adjusted Alternative-Specific Constant Coefficients

Model Term	Parameter Estimate
Alt2 – Adjusted	-5.3370
Alt3 – Adjusted	-6.5843

From the model calibrated to the population probabilities, we used a series of hypothetical scenarios to estimate the following impacts of free-ridership and NPS:

- **Scenario 1: Baseline/Actual.** This scenario represents our best estimate of the actual population shares for each alternative (Table 34).
- **Scenario 2: No Program.** Under this scenario, we determined an inferred baseline by estimating what modeled probabilities would look like absent program impacts (i.e., no program incentives and no program awareness). That is, we recalculate the population shares by using the parameter estimates shown in Table 33, but removed the incentives and program influence/awareness from the set of explanatory variables, as shown in Table 36.
- **Scenario 3: No Awareness/Influence.** Under this scenario, we estimated what the modeled probabilities would look like with incentives, but absent program awareness and influence. That is, we recalculate the population shares by using the parameter estimates shown in Table 33, but removed program awareness/influence from the set of explanatory variables, as shown in Table 36.

[13] In the non-participant surveys, we asked for information about self-reported insulation installs over a two-year period. We annualized the survey results and corrected for differences in the in-program and out-of-program installation quantity/quality by multiplying the annual installation estimate from the survey by the ratio of out-of-program to in-program insulation costs.

[14] Train. *Discrete Choice Methods with Simulation*, 2nd Edition. pp. 67.

Table 36. Model Terms Used in Hypothetical Scenarios

Model Term	Scenario 1: Baseline/Actual	Scenario 2: No Program	Scenario 3: No Awareness/Influence
Age	✓	✓	✓
Motive_Comfort	✓	✓	✓
EE_Very_Knowledgeable	✓	✓	✓
Alt2	✓	✓	✓
Incentive x Alt2	✓		✓
Home_Age x Alt2	✓	✓	✓
Gas_Heat x Alt2	✓	✓	✓
HES Influence x Ads x Alt2	✓		
Alt3	✓	✓	✓
Gas_Heat x Alt3	✓	✓	✓
HES Influence x Ads x Alt3	✓		✓
Non-participant Homeowner x Alt3	✓	✓	

Note: ✓ denotes that the model term is included in the explanatory variable set.
Note: Alternative 2 indicates being purchased with a program incentive, and Alternative 3 indicates being purchased without a program incentive.

Table 37 shows the estimated probabilities from the hypothetical scenarios. The direction of movement in the modeled probabilities follows intuition. Absent an incentive and awareness/influence (Scenario 2), the two purchase alternatives are minimized. In Scenario 3, the outside-program purchase probability decreases relative to the baseline absent awareness/influence.

Table 37. Modeled Probabilities from Observed Model and Hypothetical Scenarios

Alternative	Scenario 1: Baseline/Actual	Scenario 2: No Program	Scenario 3: No Awareness/Influence
No Purchase	91.8%	93.1%	92.3%
Purchase Through HES Program	1.43%	0.65%	1.47%
Purchase Outside HES Program	6.74%	6.21%	6.19%

We followed two steps using the estimated probabilities shown in Table 37 to estimate free-ridership, NPS, and ultimately, NTG. We first calculated a net market effect, and then disaggregate free-ridership and NPS from that net market effect.

Net Market Effect

We first estimated the net market effect of the HES Program by comparing the actual number of insulation installs (Scenario 1) to the estimated number of installs in the no-program scenario (inferred baseline, Scenario 2). Our estimate of the net market effect includes all insulation purchases, both in-program and out-of-program. To accomplish this, we first translated the population proportions in Table 37 into an estimated number of households (as shown in Table 38).

Table 38. HES Program Net Market Effects on Insulation Installs

Alternative	Scenario 1: Fitted Model/Actual		Scenario 2: No Program	
	% of Population	Size of Population	% of Population	Size of Population
No Purchase	91.8%	700,000	93.1%	710,047
Purchase Through HES Program	1.43%	10,932	0.65%	4,974
Purchase Outside HES Program	6.74%	51,405	6.21%	47,317
Total*	**100%**	**762,337**	**100%**	**762,337**

* The columns in this table may not sum to the Total row due to rounding.

From the information listed in Table 38, we then calculated the net market effect by taking the difference between the number of total insulation installations in Scenario 1 (10,932 + 51,405 = 62,337) and the number of total insulation installations in Scenario 2 (4,974 + 47,317 = 52,291). The net market effect of the HES Program is 10,047 (62,337 - 52,291) installations; that is, through audits, incentives, and advertising, the HES Program increased the number of insulation installations over and above that which would have happened absent the program by 10,047. Comparing the net market effect of 10,047 to the 10,932 HES Program installations, we get a net market effect of 0.92 (10,047/ 10,932 = 0.92).

This net market effects estimate includes both free-ridership and NPS, which we disaggregated in the next step, described below.

Disaggregate Free-ridership and Non-participant Spillover

To estimate free-ridership, we focused on the no program scenario relative to the actual scenario (Scenario 2 vs. Scenario 1). Free-ridership is a measure of the amount of program participants that received free measures or measures for which they received an incentive that would have elected to do so without an incentive. For the in-program purchases, we estimated the size of the free-ridership population by taking the ratio of the HES Program purchase alternative in the no incentive scenario to that of the baseline scenario.

As shown in Table 39, we calculated free-ridership as equal to 0.65% divided by 1.43%, or 45%. That is, 45% of the participants (approximately 4,970 homes) who purchased insulation through the HES Program would have done so absent program incentives and other program impacts.

Table 39. Modeled Probabilities from Observed Model and Hypothetical Scenarios

Alternative	Scenario 1: Baseline/Actual	Scenario 2: No Program	Scenario 3: No Awareness/ Influence
No Purchase	91.8%	93.1%	92.3%
Purchase Through HES Program	1.43%	0.65%	1.47%
Purchase Outside HES Program	6.74%	6.21%	6.19%

To estimate NPS, we focused on the no influence/awareness scenario relative to the actual scenario (Scenario 3 vs. Scenario 1). NPS attributes a portion of non-participants' program measure purchases without incentives to program influence and awareness. We estimated the size of the NPS population by calculating the difference between of the share that chose to purchase outside the HES Program alternative in the no influence/awareness scenario to the

share who chose to purchase outside the HES Program alternative in the baseline scenario. We then scaled the difference to the size of the participant population to properly estimate NPS.

From the information listed in Table 39, we calculated NPS as 6.74% minus 6.19%, or 0.55%. That is, we estimated that 0.55% of the statewide population of program-eligible single family homes (approximately 4,250 homes) purchased insulation because of HES Program awareness and/or HES Program influence. Expressed in terms of the participant population size, we calculated NPS as 4,250 divided by 10,932, or 39%.

The *separate* free-ridership and NPS estimates combine to a net market effect of 10,212 homes, which is slightly higher than the *overall* net market effect of 10,047homes stated previously. Thus, we proportionally adjusted our estimates of free-ridership and NPS to calibrate to the net market effect of 10,047estimated above. For the HES Program insulation measure, our final free-ridership estimate is 45% and our final NPS estimate is 38% (Table 40).

Table 40. Final Free-ridership and NPS for Insulation

Component	Before Calibration		Final (Calibrated)	
	# Installs	%	# Installs	%
Participants	10,932	100%	10,932	100%
- FR	- 4,970	- 45%	- 5,059	- 46%
+ NPS	+ 4,250	+ 39%	+ 4,174	+ 38%
Net Market Effect*	10,212	93%	10,047	92%

* The columns in this table may not sum to the Net Market Effect row due to rounding.

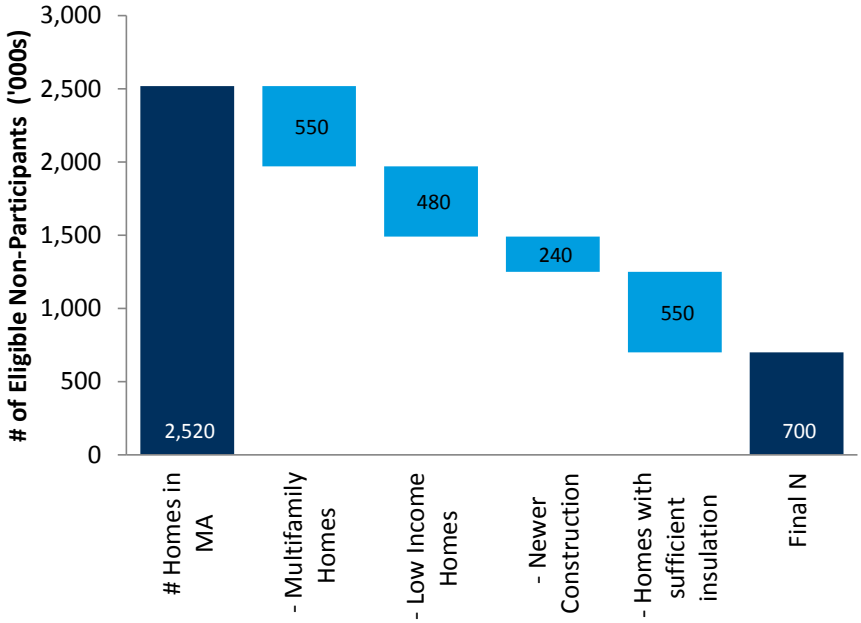
NTG Uncertainty and Confidence Interval Estimate

There are many sources of uncertainty in the estimation of HES Program insulation NTG, both quantifiable and not quantifiable. This uncertainty falls into the following two broad categories:

1. Size of the HES Program's non-participant population
2. Sampling error

The critical driver of uncertainty in the NTG estimate is the size of the non-participant population, which we estimated to be 700,000. We used several criteria in our population size estimate to exclude homes that are ineligible for the HES Program (multifamily and/or low income), and to exclude homes that are unlikely to purchase insulation through the HES Program (new construction and homes that already have sufficient insulation). This is shown in Figure 12.

Figure 12. HES Program-Eligible Insulation Population Size (Thousands)



We quantified the number of homes using data from the United States Census Bureau's 2010 ACS and the 2009 RASS. The ACS informs the multifamily, low income, and new construction criteria, while the RASS informs the sufficient insulation criteria. We adjusted our assumption of the amount of homes with sufficient insulation based on the RASS to account for the timing of this evaluation (2011 program year is two years after the completion of the RASS).

The data we used to estimate NTG is subject to sampling error, which manifests itself in uncertainty around the following:

- Model coefficients (shown in Table 33),
- Population proportions for the hypothetical scenarios (shown in Table 37), and
- Estimated net market effects.

We used a bootstrap procedure to estimate a confidence interval around the net market effect for insulation. Generally speaking, bootstrap procedures are used to heuristically estimate confidence intervals for statistical quantities where an analytical solution is too complex to characterize.

We followed a standard five step process for our bootstrap procedure:

1. Created a bootstrap sample by sampling with replacement from the original set of modeling data, in this case, the respondents from the participant and non-participant surveys. By sampling with replacement, an individual may be represented in the bootstrap sample more than one time.
2. Fitted the DC model with same specification as shown in Table 33. Note that the coefficients will vary for each bootstrap sample.

3. Estimated NTG based on the DC model in step 2 for each bootstrap sample.
4. Repeated steps 1, 2, and 3 100 times.
5. Used the 5th and 95th percentiles of the bootstrap-estimated NTGs as a 90% confidence interval for NTG.

Our bootstrap 90% confidence interval for insulation NTG is (0.73, 1.14).

Appendix D: Discrete Choice Results for Air Sealing

The Evaluation Team conducted a similar DC analysis for air sealing as we did for insulation. Using data from the same set of participant and non-participant surveys, we fit a model with the same specification as that shown in Table 33 to obtain the model coefficients shown in Table 41. The incentive amount we used in our model reflects the full cost of the air sealing measure, as this is effectively a direct install measure in the HES Program.

Table 41. Final Model Parameter Estimates for Air Sealing

Model Term	Parameter Estimate	t Value
Age	-0.0020	-0.68
Motive_Comfort	0.3266	3.81
EE_Very_Knowledgeable	0.4823	5.46
Alt2	-4.0753	-14.65
Incentive x Alt2	0.0048	15.04
Home_Age x Alt2	-0.0116	-5.93
Gas_Heat x Alt2	-0.3694	-2.99
HES Influence x Ads x Alt2	0.1397	5.67
Alt3	-4.5161	-19.70
Gas_Heat x Alt3	1.9406	11.51
HES Influence x Ads x Alt3	0.4700	3.73
Non-participant Homeowner x Alt3	0.3043	5.67

Note: Alternative 2 indicates being purchased with a program incentive, and Alternative 3 indicates being purchased without a program incentive.

As with insulation, the survey samples differ from the true population probabilities (shown in Table 42). Less than 1% of the 2011 qualified homes purchased air sealing through the HES Program (approximately 10,000 HES Program air sealing jobs), while non-participant survey results indicate that a slightly larger number of households purchased air sealing outside of the HES Program (approximately 1.37% per year).

Table 42. Observed and Modeled Probabilities by Alternative – Air Sealing

Alternative	Observed Sample Probability	Modeled Probability	Population Probability
No Purchase	85%	85%	97.8%
Purchase Through HES Program	8%	8%	0.83%
Purchase Outside HES Program	7%	7%	1.37%

Again, we adjusted the coefficients on the alternative specific constants listed in Table 42 in order to calibrate the model-estimated probabilities for each alternative to those of a statewide population, rather than to the observed sample. After adjusting the alternative-specific coefficients, we estimated population shares for three scenarios: baseline, no program, and no awareness/influence (Table 43).

Table 43. Modeled Probabilities from Observed Model and Hypothetical Scenarios

Alternative	Scenario 1: Baseline/Actual	Scenario 2: No Program	Scenario 3: No Awareness/Influence
No Purchase	97.8%	98.7%	98.0%
Purchase Through HES Program	0.82%	0.06%	0.83%
Purchase Outside HES Program	1.37%	1.22%	1.22%

Note: Columns may not add to 100% due to rounding.

Net Market Effect

We used the estimated shares listed in Table 43 to calculate the overall net market effect and the free-ridership and NPS components of NTG. Table 44 expresses the population proportions in Table 43 as a number of households.

Table 44. HES Program Net Market Effects on Insulation Installs

Alternative	Scenario 1: Fitted Model/Actual		Scenario 2: No Program	
	% of Population	Size of Population	% of Population	Size of Population
No Purchase	97.8%	1,222,522	98.7%	1,234,026
Purchase through HES program	0.82%	10,348	0.06%	688
Purchase outside HES program	1.37%	17,130	1.22%	15,286
Total*	**100%**	**1,250,000**	**100%**	**1,250,000**

* The columns in this table may not sum to Total row due to rounding.

From the information listed in Table 44, we calculated the net market effect by taking the difference between the number of air sealing installations in Scenario 1 (10,348 + 17,130 = 27,478) and the number in Scenario 2 (688 + 15,286 = 15,974).The net market effect of the HES Program is 11,503 (27,478 - 15,974) installations. Comparing the net market effect of 11,503 to the 10,348 HES Program installations, we get a net market effect of 1.11 (11,503 / 10,348 = 1.11).Table 45splits the net market effect into free-ridership (7%) and NPS (18%) using a method similar to that presented in Appendix C.

Table 45. Final Free-ridership and NPS, Air Sealing

Component	Before Calibration		Final (Calibrated)	
	# Installs	%	# Installs	%
Participants	10,348	100%	10,348	100%
- FR	690	7%	684	7%
+ NPS	1,821	18%	1,839	18%
Net Market Effect*	11,478	111%	11,503	111%

* Rows in table may not sum to Net Market Effect row due to rounding

Our bootstrap 90% confidence interval for air sealing NTG is (1.03, 1.21).