Central Hudson Gas & Electric Corporation

Residential Electric HVAC Program

2010-2012 Impact Evaluation · November 2015

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Executive Summary

Applied Energy Group, Inc. (AEG) was retained by Central Hudson Gas & Electric (Central Hudson) to conduct an impact evaluation of its Residential Electric HVAC Program for 2010 through 2011. The program offers Central Hudson's residential electric customers up to $500 in rebate incentives to purchase energy efficient HVAC systems, including central air conditioners and air-source heat pumps. The program offers incentives for additional HVAC measures including electronically commutated motor (ECM) furnace fans, water heaters, and programmable thermostats.

The impact evaluation includes engineering and billing analyses to determine the energy and demand savings attributable to the program. AEG conducted an ex-post engineering review using energy and demand savings algorithms provided by the *2010 New York Standard Approach Manual for Estimating Energy Savings from Energy Efficiency Programs* (Tech Manual). The billing analysis involved a fixed effects model to compare the difference in energy usage between a participant treatment group and to a control group of non-participants.

In July 2012, AEG conducted a survey of 69 randomly selected program participants to evaluate the effects of free ridership and spillover at a 90/10 level of confidence and precision. In addition to the survey, AEG conducted an HVAC metering study to determine energy usage profiles for heating and cooling end-uses. Although the metering study did not attain sufficient participation to be considered statistically significant, the anecdotal results are reported in the impact evaluation. Details about the HVAC metering study are included in Appendix A of the report.

AEG determined that the NTG factor for the program was 87 percent, which includes both free ridership and spillover estimates. The NTG factor was applied to the ex post analysis results to determine the net savings attributable to the program.

Table ES1 NTG Summary

Free Ridership	Spillover	NTG Factor
30%	17%	87%

AEG determined that the program resulted in a total net savings of 1,305,306 kWh for the ex post analysis. The ex post net savings are shown in the table below along with the EEPS scorecard savings and associated realization rate.

Table ES2 Total Net Savings Summary

Source	Net Energy Savings (kWh)	Net Demand Savings (kW)
Ex post analysis	1,305,306	443
EEPS Scorecard	1,340,846	338
Realization Rate	97%	131%

This impact evaluation describes the methodology used by AEG to determine the energy and demand savings attributable to the Residential Electric HVAC Program. The impact evaluation reports the results of AEG's savings analysis and assesses the overall cost-effectiveness of the program.

Introduction

Program Background

Central Hudson Gas & Electric Corporation (Central Hudson) is a regulated transmission and distribution utility serving approximately 300,000 electric and 75,000 natural gas customers in eight counties of New York State's Mid-Hudson River Valley. Central Hudson delivers natural gas and electricity in a 2,600 square-mile service territory that extends north from the suburbs of metropolitan New York City to the Capital District around Albany.

In June 2008, the New York Department of Public Service (DPS) initiated a statewide effort to reduce electricity and natural gas usage under the Energy Efficiency Portfolio Standard (EEPS).[1] The EEPS regulations established goals to reduce electricity usage by 15 percent of forecasted levels by 2015 as well as similar reduction targets for natural gas.

Applied Energy Group, Inc. (AEG) was retained by Central Hudson to conduct an impact evaluation of its Residential Electric HVAC Program for program years 2010 through 2011. The program offers residential electric customers rebate incentives to purchase energy efficient HVAC systems, including central air conditioners and air-source heat pumps. The program offers incentives for additional HVAC measures including electronically commutated motor (ECM) furnace fans, water heaters, and programmable thermostats. Per program rules, other measures such as ECM furnace fans must be installed with another qualifying HVAC system. The table below shows the rebate levels for each measure offered through the program.

Table 3 Rebate Levels

Measure	Rebate
Central Air Conditioners	
Tier 1, SEER ≥ 15; EER ≥ 12.5	$100
Tier 2, SEER ≥ 16; EER ≥ 13	$300
Air-Source Heat Pumps	
Tier 1, SEER ≥ 15; EER ≥ 12; HSPF ≥ 8.5	$350
Tier 2, SEER ≥ 16; EER ≥ 13; HSPF ≥ 9	$500
Other Measures	
ECM Fan	$200
Heat Pump Water Heater	$400
Programmable Thermostat	$25
Air Sealing	$100/hour, Up to 6 hours

HVAC equipment that meets program requirements must be installed by a participating SavingsCentral Trade Ally, with the exception of heat pump water heaters, which may be installed by the customer. Overall a total of 2,338 eligible measures were acquired in 1,325 customer households from 2010 through 2011. Note that the analysis of program tracking data revealed that 49 customer accounts had

[1] NY PSC Order, Case 07-M-0548 June 23, 2008

installed 70 thermostats that did not meet the eligibility requirements.[2] The savings attributable to these ineligible measures are not included in the impact evaluation. The total eligible participation for each measure type is shown in the table below.

Table 4 Total Participants, 2010-2011

Measure	Measures	Accounts	Measures/Account
Central Air Conditioning Tier 1	43	39	1.10
Central Air Conditioning Tier 2	610	578	1.06
Central Air Source Heat Pump Tier 1	356	320	1.11
Central Air Source Heat Pump Tier 2	207	176	1.18
Air Sealing	30	30	1.00
ECM Furnace Fan	208	194	1.07
Heat Pump Water Heater	173	173	1.00
Programmable Thermostat	711	637	1.12
Program Total	2,338	1,325	1.76

Impact Evaluation Overview

AEG determined the energy and demand savings attributable to the program based on Options B and C of the International Performance Measurement and Verification Protocols (IPMVP). AEG conducted an ex post analysis of program tracking data to determine gross energy and demand savings and performed a statistical billing analysis of program impacts for Option C.

An HVAC metering study was attempted to fulfill IPMVP Option B; however, the study did not achieve sufficient participation to represent the overall program population. The metering study is described in Appendix A of this report. The table below summarizes the measurement and verification approaches used for this impact evaluation.

Table 5 Measurement & Verification IPMVP Approach

M&V Approach	IPMVP Option	Description
Onsite Metering	Option B: Retrofit Isolation – All Parameter Measurement	Verify energy savings by monitoring HVAC energy consumption and real-time performance data.
Billing Analysis	Option C: Whole-Facility Analysis	A regression analysis of customer billing data to observe any changes in participants' energy usage as a result of the program.

[2] In particular, the thermostats were not installed with a qualifying HVAC system per program rules.

Engineering Analysis

Ex Post Analysis Methodology

AEG conducted an ex post analysis using energy and demand savings algorithms provided by the *2010 New York Standard Approach Manual for Estimating Energy Savings from Energy Efficiency Programs* (Tech Manual).[3] The Tech Manual is approved by the New York Public Service Commission to provide a standardized, fair and transparent approach for determining program savings. AEG supplemented the Tech Manual approach with utility-specific inputs developed using primary data such as the program tracking information and the 2013 Residential Appliance Saturation Survey (RASS).[4] The specific equations and methodologies used to determine energy and demand savings are described below for each measure type.

Central Air Conditioners and Central Air Source Heat Pumps

The gross energy and demand savings for central air conditioners and air source heat pumps were calculated using the following equations. Note that heat pumps include energy savings from both heating and cooling end-uses, while air conditioners include energy and peak demand savings from the cooling element.

$$\Delta kWh = \left[tons \times \left(\frac{12}{SEER_{base}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}\right] + \left[kBTU_{out} \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}\right]$$

$$\Delta kW = tons \times \left(\frac{12}{EER_{base}} - \frac{12}{EER_{ee}}\right) \times CF$$

Where:

ΔkWh	*= gross annual energy savings*
ΔkW	*= gross coincident demand savings*
tons	*= tons of air conditioning, based on nameplate data*
$kBTU_{out}$	*= the nominal rating of the heating output capacity of the heat pump in kBtu/hr*
SEER	*= seasonal average energy efficiency ratio. (Btu/watt-hour)*
EER	*= energy efficiency ratio under peak conditions (Btu/watt-hour)*
EFLH	*= heating or cooling equivalent full-load hours*
HSPF	*= heating seasonal performance factor (Btu/watt-hr)*
CF	*= coincidence factor*
12	*= conversion factor (kBtuh/ton)*

[3] *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*, Prepared for New York Department of Public Service by TecMarket Works, October 15, 2010.

[4] Energy Management Survey, Prepared for Central Hudson Gas & Electric Corporation by Opinion Research Specialists, LLC, 2013.

Program tracking data specifically characterizing the installed measures served as the basis for variable inputs in the equations. However, the Tech Manual algorithms called for several inputs that were not identified in the program tracking data. The following table summarizes the values used for key variables in the savings equation that were not included in the program tracking data. These inputs generally include constant variables that are applied uniformly across the participant population.

Table 6 Air Conditioner and Heat Pump Variable Assumptions

Variable	Value	Description
$SEER_{base}$	13	Federal minimum standard
EER_{base}	11.09	Tech Manual Default
CF	0.8	Tech Manual Default
$EFLH_{cool}$	470	Tech Manual default for single family detached home of average vintage in Poughkeepsie, NY
$EFLH_{heat}$	1,157	
$HSPF_{base}$	8.1	Tech Manual Default

Other Measures

The gross energy and demand savings for other measures including air sealing, ECM furnace fans, electric heat pump water heaters, and programmable thermostats were calculated using Tech Manual equations, which largely relied on default assumptions provided by the Tech Manual. The specific methods used for each measure type are described below.

Electric Heat Pump Water Heater

Gross energy savings attributable to electric heat pump water heaters is largely determined by the difference in the energy factor of the efficient and baseline units. According to the Tech Manual, demand savings for electric heat pump water heaters are a constant deemed savings value. The following equations show how savings were calculated.

$$\Delta kWh = units \times \frac{GPD \times 365 \times 8.33 \times \overline{\Delta T}}{3413} \times \left[\frac{1}{EF_{base}} - \frac{1}{EF_{ee}}\right]$$

$$\Delta kW = 0.5$$

Where:

ΔkW	*= gross coincident demand savings*
ΔkWh	*= gross annual energy savings*
Units	*= number of high efficiency water heaters installed under the program*
GPD	*= average daily water consumption (gallons/day)*
$\overline{\Delta T}$	*= average difference between the cold inlet temperature and the hot water delivery temperature (°F)*
EF_{base}	*= baseline water heater energy factor*
EF_{ee}	*= efficient water heater energy factor*
3413	*= conversion factor (Btu/kWh)*
8.33	*= conversion factor (Btu/gallon to °F)*
365	*= conversion factor (days/yr)*

Standard Tech Manual input assumptions were used to calculate the savings attributable to electric heat pump water heaters for all variables. The following table summarizes the values used for key variables in the savings equation as defined in the Tech Manual.

Table 7 Electric Heat Pump Water Heaters Variable Assumptions

Variable	Value	Description
GPD	78	Tech Manual default for four people
$\overline{\Delta T}$	71.7	Average change in temperature from water main (58.4°F) to water heater set point (130°F)
EF_{base}	0.88	Weighted average based on RASS
EF_{ee}	2.0	Minimum program requirement. EF was not included in tracking data.

Programmable Thermostat

The gross energy savings attributable to a programmable thermostat are primarily driven by the energy savings factor (ESF) applied to the HVAC system usage. There are no demand savings attributable to programmable thermostats. According to the Tech Manual, thermostat savings should be calculated per residence rather than per thermostat. Following this guidance, AEG calculated eligible thermostat savings using the total cooling and/or heating capacity installed through the program. The method used to calculate the gross energy impacts is described in the following equation.

$$\Delta kWh = \left(Tons \times \frac{12}{SEER} \times EFLH_{cool} \times ESF_{cool}\right) + \left(kBTUh_{out} \times \frac{EFLH_{heat}}{HSPF} \times ESF_{heat}\right)$$

Where:

ΔkWh	*= gross annual energy savings*
Tons	*= total tons of air conditioning per residence*
SEER	*= seasonal average energy efficiency ratio (Btu/watt-hour)*
12	*= conversion factor (kBtuh/ton)*
ESF	*= energy savings factor*
$kBTUh_{out}$	*= the nominal rating of the heating output capacity of the heat pump in kBtu/hr (including supplemental heaters)*
HSPF	*= heating seasonal performance factor (Btu/watt-hr)*
EFLH	*= heating equivalent full-load hours*

AEG used a combination of program tracking data and Tech Manual assumptions to determine the gross energy savings attributable to programmable thermostats. The following table summarizes the key variables used in the equation.

Table 8 Programmable Thermostat Variable Assumptions

Variable	Value	Description
Tons	Application	Total cooling capacity rebated through the program
$kBTUh_{out}$	Application	Total heating capacity rebated through the program
SEER	Application	Cooling efficiency of the rebated HVAC system
ESF_{cool}	0.09	Tech Manual Default
ESF_{heat}	0.07	Tech Manual Default
HSPF	Application	Heating efficiency of the rebated heat pump system
$EFLH_{cool}$	470	Tech Manual default for single family detached home of average vintage in Poughkeepsie, NY
$EFLH_{heat}$	1157	

Air Sealing

AEG calculated the gross energy and demand savings for air sealing measures using Tech Manual methods for airflow improvements as a result of the program. First, a conservative estimate of airflow changes was modeled based on the minimum airflow reduction as a result of the air sealing measures. Next, the airflow changes were used to determine gross energy and demand savings in accordance with the Tech Manual. The following equation was used to calculate the airflow changes and the associated savings due to the program.

$$\Delta CFM50 = ((ACHbase - ACHee) * Volume / 60) * n\text{-}factor$$

$$\Delta kW = \Delta CFM50 / n\text{-}factor * (\Delta kW/CFM) * CF$$

$$\Delta kWh = \Delta CFM50 / n\text{-}factor * (\Delta kWh/CFM)$$

Where:

ΔCFM_{50}	= change in infiltration rate (cfm) at measured 50 Pa
ACHbase	= air changes per hour before installing air sealing
ACHee	= air changes per hour after installing air sealing
Volume	= average cubic feet of home
N-factor	= correction from CFM50 to natural infiltration rate
ΔkW/CFM	= electricity demand savings per CFM of infiltration reduction
ΔkWh/CFM	= electricity consumption savings per CFM of infiltration reduction
CF	= coincidence factor

AEG used a combination of program performance data supplemented with available primary and secondary data from customer surveys and Tech Manual guidance. The following table summarizes the values used to calculate air sealing savings.

Table 9 Air Sealing Variable Assumptions

Variable	Value	Description
N-factor	15	Tech Manual default for 2 story home with normal wind exposure in NY climate
ΔkW/CFM	0.004	Weighted average based on HVAC type from RASS and Tech Manual Appendix E: Opaque Shell Measure Savings
ΔkWh/CFM	5.6	
CF	0.8	Default coincidence factor from Tech Manual
Volume	14.8	Average volume (kft^3) of customer home based on RASS
ACHbase	0.50	Tech Manual default for average vintage home.
ACHee	0.45	Based on 10% program minimum air change reduction from air sealing measure

ECM Furnace Fans

The Tech Manual provides a fixed value for the gross energy and demand savings attributable to ECM furnace fans. The gross energy savings per measure is 733 kWh and there are no demand savings.

Ex Post Analysis Results

AEG calculated the expected energy and demand savings for each measure using the Tech Manual engineering algorithms described above. The total savings reflect the sum of energy and demand impacts attributable to eligible participants. The results of the ex post analysis are presented in the following table.

Table 10 Gross Ex Post Results

Measure	Measures	kWh/Unit	kW/Unit	Total kWh	Total kW
Central Air Conditioning Tier 1	43	246	0.33	10,589	14
Central Air Conditioning Tier 2	610	257	0.38	156,575	234
Central Air Source Heat Pump Tier 1	356	721	0.26	256,530	93
Central Air Source Heat Pump Tier 2	207	1,146	0.38	237,272	78
Air Sealing	30	70	0.04	2,095	1
ECM Furnace Fan	208	733	-	152,464	-
Heat Pump Water Heater	173	3,176	0.50	549,459	87
Programmable Thermostat*	637	203	-	129,170	-
Total Program				**1,494,155**	**507**

** Thermostat savings are shown per account not per measure according to Tech Manual guidance.*

Net Impact Analysis

Net-to-Gross Methodology

Net savings refers to the amount of savings attributable to the program after accounting for free ridership and spillover. Free ridership refers to those participants who would have installed the efficient measures without the program influence. Spillover refers to additional savings achieved as a result of the program, but that were not directly incentivized through the program. The net-to-gross (NTG) factor is calculated by the following equation:

$$NTG = 1 - Free\ ridership + Spillover$$

In July 2012, AEG conducted a survey of 69 randomly selected program participants to evaluate the effects of free ridership and spillover. Results of the survey are statistically significant at the 90 percent confidence level and a margin of error of +/- 10 percent. The full participant survey instrument and approved NTG scoring algorithms are included in Appendix B and C of this report.

Free Ridership Analysis

Free ridership refers to those participants who would have installed the efficient measures without the program influence. Two questions in the participant survey were designed to assess the effects of free ridership.

- **Question 1:** Were you planning to purchase a new heating or cooling system with the exact same efficiency within three months before or after purchasing this equipment?
- **Question 2:** How likely is it that you would have purchased and installed equipment with the exact same efficiency within 3 months of when you did participate in the program if the utility had not offered the rebate?

Responses to the free ridership questions were assigned a probability suggesting that the respondent was a free rider. The free ridership probability reflects the likelihood that a respondent would have installed the efficient measures absent the program. The proportion of each response was multiplied by the free ridership probability to calculate the free ridership score. The tables below show how the free ridership score was determined for each question.

Table 11 Question 1 Free Ridership

Response	Probability	Count	Weight (n=66)	Score
Yes	25%	20	30%	8%
No	0%	46	70%	0%
Question 1 Free Ridership Score				8%

Table 12 Question 2 Free Ridership

Response	Probability	Count	Weight (n=67)	Score
Very unlikely	0%	12	18%	0%
Somewhat unlikely	20%	6	9%	2%
Neither likely or unlikely	40%	9	13%	5%
Somewhat likely	60%	11	16%	10%
Very Likely	80%	29	43%	35%
Question 2 Free Ridership Score				52%

The free ridership scores were averaged to determine the overall free ridership factor for the program. The overall free ridership is presented in the following table. Based on the responses to the survey questions, free ridership was estimated at 30 percent.

Table 13 Free Ridership Summary

Free Ridership Question	Score
Question 1	8%
Question 2	52%
Program Free Ridership	30%

Spillover Analysis

Spillover refers to additional savings achieved as a result of the program, but that were not directly incentivized through the program. Three questions in the participant survey were designed to assess the effects of spillover.

- **Question 1:** Have you taken any other steps to reduce energy use in your home as a result of your participation in the program?
- **Question 2:** Have you completed any of the following actions as a result of your participation in the program?
- **Question 3:** On a scale of 1-10 with 10 being very important and 1 meaning little importance, what influence did the program have in your decision to take additional energy efficiency actions in your home?

The spillover factor is calculated as the ratio of net spillover savings to gross savings of the participant sample. The following equation was used to calculate the spillover factor based on spillover question responses.

$$Spillover = \frac{Net\ Spillover\ Savings}{(Program\ Savings\ per\ Participant \times Total\ Respondents) + Total\ Spillover\ Savings}$$

Where:

Net Spillover Savings = Sum product of gross spillover savings multiplied by the spillover score for each respondent
Program Savings per Participant = Average participant savings in the sample
Total Respondents = Total survey respondents
Total Spillover Savings = Sum of gross spillover savings for all spillover respondents

Respondents were asked a series of questions regarding any additional energy savings actions they engaged in as a result of the program. Spillover actions included CFL lighting, energy efficient appliances, appliance recycling, and insulation. Energy savings were calculated based on the reported actions using algorithms found in the Tech Manual. The savings for each participant were weighted by that participant's spillover score to calculate the net spillover savings.

The table below shows how the spillover factor was calculated using survey results and the spillover equation described above. AEG determined that the spillover score for the program was 17 percent.

Table 14 Spillover Summary

Line	Variable	Value
A	Total Respondents	69
B	Program Savings per Participant	1,128
C	Program Savings of Sample (A x B)	77,809
D	Gross Spillover Savings of Sample	24,392
E	Total Sample Savings (C + D)	102,201
F	Net Spillover Savings	17,343
G	Spillover Score (F ÷ E)	17%

Net Results Summary

The results of the free ridership and spillover analyses were used to derive the NTG factor with the equation above. The table below shows that the NTG factor for the program was 87 percent.[5]

Table 15 Net-to-Gross Summary

Free Ridership	Spillover	NTG Factor
30%	17%	87%

The net program savings were determined by applying the NTG ratio to the total gross savings results from the engineering analyses. The billing analysis constituted a net impacts model; therefore, no further adjustment of the billing analysis results is necessary to reflect net savings. The net gross savings from the engineering analysis are shown in the following table.

[5] Note that percentages may not sum due to rounding.

Table 16 Net Ex Post Results

Measure	Measures	kWh/Unit	kW/Unit	Total kWh	Total kW
Central Air Conditioning Tier 1	43	215	0.29	9,251	12
Central Air Conditioning Tier 2	610	224	0.34	136,786	204
Central Air Source Heat Pump Tier 1	356	630	0.23	224,107	81
Central Air Source Heat Pump Tier 2	207	1,001	0.33	207,283	68
Air Sealing	30	61	0.03	1,830	1
ECM Furnace Fan	208	640	-	133,194	-
Heat Pump Water Heater	173	2,775	0.44	480,012	76
Programmable Thermostat*	637	177	-	112,844	-
Total Program				**1,305,306**	**443**

** Thermostat savings are shown per account not per measure according to Tech Manual guidance.*

Program Realization Rate

The total program savings from the engineering analysis was compared to the total scorecard savings obtained from the NYDPS website. Central Hudson is required to report program savings on monthly scorecards submitted to the NYDPS. The total reported savings from 2010 through 2011 was used to calculate the realization rate. The table below shows the realization rate using the gross and net savings from the ex-post engineering analysis divided by the total scorecard savings.

Table 17 Program Realization Rate

Savings Type	Gross kWh	Net kWh	Gross kW	Net kW
Scorecard Savings	2,828,258	2,545,432	736	662
Scorecard Savings (Corrected)	1,489,829	1,340,846	376	338
Ex Post	1,494,155	1,305,306	507	443
RR	53%	51%	69%	67%
RR (Corrected)	100%	97%	135%	131%

The realization rate was calculated using both the original year-end Scorecard savings submitted to the DPS for 2010 and 2011. After discussions with Central Hudson and program implementation staff, the project team identified a typographical error in the original Scorecard savings. A misplaced decimal point in the savings reported for December 2011 resulted in an inaccurate realization rate.[6] However, the corrected Scorecard savings yields a realization rate that is more consistent with expectations. Central Hudson subsequently corrected the savings Scorecard as a result of the evaluation effort.

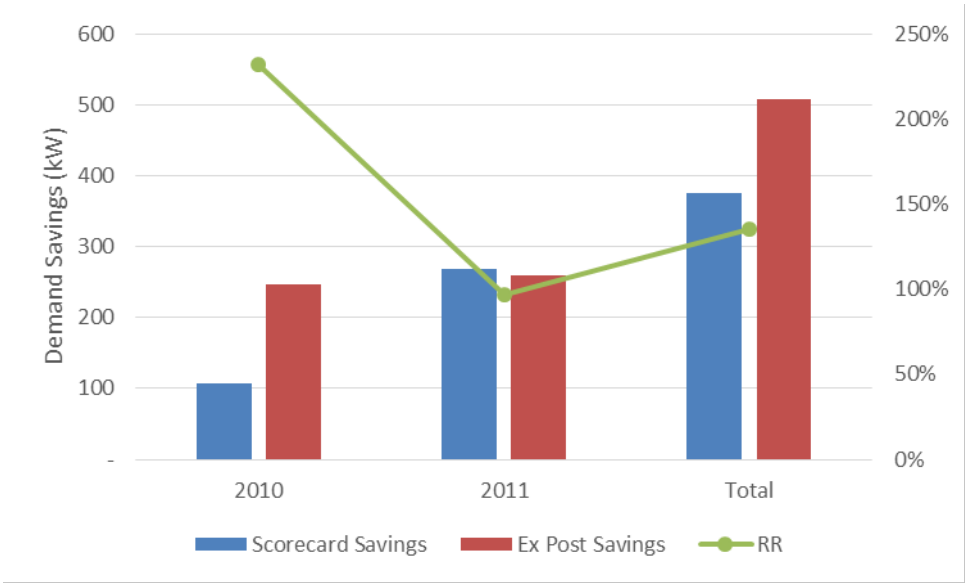
The corrected gross realization rate for energy savings is 100% compared to a 97% realization rate for net savings. The discrepancy between the net and gross realization rate arises from the difference in net-to-gross assumptions between the Scorecard and the ex post analysis. The Scorecard savings

[6] The December 2011 Scorecard showed savings of 1,487 MWh. The average savings from the preceding 3 months was 135 MWh. Participation in December 2011 is comparable to the previous 3 months, so AEG concluded the December 2011 Scorecard should have been reported as 148.7 MWh.

assumes a deemed NTG factor of 90 percent, however, the NTG factor for the ex post analysis is 87 percent based on survey analysis conducted for this evaluation.

There is a difference in realization rates between program years, which is due to a difference in the methodology for calculating savings for the Scorecards in each program year. According to Central Hudson and program implementation staff the Scorecard savings for 2010 were based on deemed values, whereas the values for 2011 were calculated based on application data. Analysis of the tracking data showed that the deemed demand savings for 2010 were substantially lower than 2011. The following figure illustrates the realization rate difference between 2010 and 2011.

Figure 1 Gross Demand Realization Rate, Corrected



Billing Analysis

Billing Analysis Methodology

AEG conducted a statistical billing analysis to estimate the observed changes in energy usage attributable to the program. The analysis approach included: 1) the development of a matched control group for program participants, and 2) the estimation of a fixed effects model to determine measure-level savings. Each aspect of the analysis is described in more detail in the sections below.

The billed energy usage for all electric and gas customers within the service territory were obtained from Central Hudson. The billing data consisted of energy (kWh) usage data at bi-monthly intervals spanning approximately two years before and after the program was implemented, giving a total of four years of billing data. Billing data was merged with program tracking data to perform the analysis.

AEG included weather data obtained from the National Oceanic and Atmospheric Administration (NOAA) in the model. The weather data included average daily temperatures recorded at Poughkeepsie Dutchess County Airport to reflect weather conditions within the Central Hudson service territory.[7] A base temperature of 65°F was used to calculate heating and cooling degree days over the duration of the program (consistent with generally accepted evaluation procedure).[8]

Analysis Pool

The analysis pool consists of customer accounts that were exclusively identified in the Residential Electric HVAC Program tracking data and no other programs offered by Central Hudson. A total of 1,459 unique customer accounts participated in the program from 2010 through 2011. The following table describes the screening criteria for the analysis pool.

Table 18 Analysis Pool Screening Criteria

Criteria	Accounts Removed	Balance of Accounts
Residential HVAC Electric Program participants	0	1,459
Participants in other Central Hudson Programs	600	859
Account matched to utility billing data	73	786
Accounts with at least one full year of pre- and post-treatment data	72	714

As a result of the screening criteria, 714 participants were included in the final analysis pool.

Control Group

A stratified matching technique was used to construct a control group that was very similar to the participant group in all observable ways, except for being exposed to the program treatment. The method for creating the control group included two basic steps. First, filters were applied to participants

[7] Temperature data was recorded at a NOAA weather station located at the Dutchess County Airport located in Wappingers Falls, NY.

[8] The EIA defines degree-days as relative measurements of outdoor air temperature used as an index for heating and cooling energy requirements. Heating degree-days are the number of degrees that the daily average temperature falls below 65°F. Cooling degree-days are the number of degrees that the daily average temperature rises above 65°F.

and non-participants to create demographic buckets by rate code and by SIC code. Next, each participant's pretreatment billing data was compared to each control customer's billing data (during the same time-period) using a Euclidean distance metric to find the best match. The distance metric used is described in the equation below.

$$Distance = \sqrt{\sum_{i=1}^{n} (kWh\ Usage_{treatment} - kWh\ Usage_{control})^2}$$

The metric calculates the difference between the treatment and control customer's usage in each billing period *i* and sums them over all billing periods *n*. Once the distance was calculated for each treatment customer and every potential control customer within each bucket, the control customer that minimizes the difference in billing usage for each participant in our dataset was selected for the control group.

During this process, there were treatment customers who didn't have a good "fit" with a control group pair or their control group pair was already matched to a different participant. Therefore, these participants were dropped from the analysis. After the matching process was completed, a total of 699 participants and 699 control customers were used in the analysis.

Because this evaluation was not conducted as a rigorously designed experiment, it is important to discuss the presence of self-selection bias. Self-selection bias is caused by the systematic differences between customers who volunteer for a program and those who do not. Self-selection bias is problematic because the estimates of savings cannot be separated from the systematic differences between treatment and control customers.

The best way to eliminate self-selection bias is to evaluate the program using a randomized control trial (RCT), where those that want to participate are randomly assigned to either a treatment group or control group. RCT's are both popular and feasible in a pilot setting, however, because this is a fully implemented voluntary rebate program, an RCT was not an option. The second best approach for this type of program is a quasi-experimental design, or matched control group, as described above. Creating a matched control group based on observable characteristics (particularly pre-treatment energy consumption) can significantly reduce any self-selection bias. However, because the results of a designed experiment cannot be fully duplicated through matching, the matches necessarily have some level of bias, and the estimates will also have some level of uncertainty.

Fixed Effects Analysis

AEG used a fixed effects model as the primary analysis tool to estimate savings. A fixed effects model is a linear regression model widely used in the industry to analyze cross-sectional time-series datasets. In this case, each cross section represents a single customer (treatment or control) and the time-series represents the data over time including one year of pre-treatment data and one year of post treatment data.

The fixed effect in the fixed effects model, is actually a customer specific intercept term (or dummy variable) that isolates customer-specific variation allowing the model to obtain better estimates of the savings. The model leverages differences between customers and over time to estimate the impact or savings associated with specific measures as follows:

- Differences in consumption between customers that receive the treatment and those that don't (treatment vs. control) during the treatment period
- Differences in consumption between participants' usage in the pre and post treatment periods
- Differences in consumption between participant and control customers during the pre-treatment period.

In addition, weather and calendar variables are included in the model to capture those effects and capture the effect of weather on savings.

For this program, if each participant only received a single measure the savings for each measure could be estimated more easily. However, many of the participants had multiple measures installed. Unfortunately, due to the timing of the installations (some happening at the same time, and others happening at different times) it would be very difficult if not impossible to obtain estimates of savings for a single measure at a multi-measure site.

Therefore, in order to account for the presence of multiple measures categories were created for single and multi-measure installations as shown in the table below. In addition to grouping multi-measure installations together, some of the single measure installations were grouped together if they were very similar. The model does not distinguish between savings for Tier 1 or Tier 2 CAC and Heat Pump installations.

Table 19 Number of Customers in Each Measure Category

Measure Category	Category Definition	Number of Participants
Single Rebate Measures		
Central Air Conditioning	Tier 1 or Tier 2 CAC Rebate	95
Heat Pump	Tier 1 or Tier 2 Heat Pump Rebate	134
ECM Furnace Fan	Furnace Fan Rebate	8
Electric Air Sealing	Air Sealing Rebate	21
Electric Water Heater	Water Heater Rebate	98
Programmable Thermostat	Programmable Thermostat Rebate	10
Multiple Rebate Measures		
CAC and Furnace Fan	Both CAC and Furnace Fan Rebates	5
CAC and Programmable Thermostat	Both CAC and Prog. Thermostat Rebates	163
CAC and Prog. Thermostat and Furnace Fan	CAC and Prog. Thermostat and Furnace Fan Rebates- All Three	22
Heat Pump and Furnace Fan	Both HP and Furnace Fan Rebates	16
Heat Pump and Programmable Thermostat	Both HP and Prog. Thermostat Rebates	59
HP and Prog. Thermostat and Furnace Fan	HP and Prog. Thermostat and Furnace Fan Rebates- All Three	50
Other Multiple Rebates	Unaccounted participants with multiple measures installed	18
Total Participants		**699**

Once the participants were assigned to categories based on the number and type of measures installed, the savings for each measure combination were able to be estimated.

Model Specification

The model specification was of the following form:

$$kwh_{it} = \alpha_i + \beta_1 Participation(j)_{it} + \beta_2 (Participation(j)_{it} * Weather_{it}) + \beta_3 Weather_{it} + \gamma Month_t + \varepsilon_{it}$$

kwh_{it} = bi-monthly consumption of customer *i* in period *t*

α_i = a fixed effect for each customer *i*

$\gamma Month_t$ = a vector of seasonal monthly indicator variables

$\beta_1 Participation(j)_{it}$ = a vector of participation indicator variables; one for each measure category *j* that take on a value of one after customer *i* installed their first measure

$\beta_2 (Participation(j)_{it} * Weather_{it})$ = a vector of interactions between participation in each measure combination *j* with weather

$\beta_3 Weather_{it}$ = a vector of two variables: the CDD (cooling degree days) and HDD (heating degree days) for each bi-monthly period *t*

ε_{it} = the error for participant *i* on period *t*

The model specified above allowed us to estimate the average bi-monthly savings impacts of each measure combination at various monthly temperatures throughout the year.

Measure Significance

The individual statistical significance of each of the measure combinations in the model was tested to validate the model. In addition, the joint significance of each participation variable with their weather interaction terms was tested to see if together the variables were significant in the model.

The "Other" and "Programmable Thermostat" categories were both individually and jointly insignificant. Therefore, the model was run without those 28 participants and 28 control customers belonging to those categories.

Individually the "CAC and Furnace Fan" and "Electric Air Sealing" categories were found to be statistically insignificant. However, these measure categories were kept in the model as they were each jointly significant as a group with their weather interaction terms.

Billing Analysis Results

Results of the billing analysis show that four measure combinations have positive savings values, including: Central AC with a Fan, Central AC with a Thermostat and a Furnace Fan, Furnace Fan, and Water Heater. The full results are shown in the table below.

Table 20 Average Monthly and Annual Impacts for Each Measure Combination[9]

Month	CAC	CAC Fan	CAC Therm.	CAC Therm. Fan	Heat Pump	HP Fan	HP Therm.	HP Therm. Fan	Air Seal	Furnace Fan	Water Heater
Jan	86	329	150	224	-136	-647	-256	-213	60	-54	-86
Feb	50	288	106	170	-111	-534	-205	-158	50	-28	-73
Mar	-26	201	15	55	-57	-294	-95	-41	31	29	-44
Apr	-41	183	-4	31	-46	-244	-72	-16	24	40	-34
May	-121	92	-100	-89	11	7	43	107	-24	99	51
Jun	-136	75	-118	-112	22	55	65	130	-44	111	90
Jul	-144	66	-128	-124	27	80	76	142	-116	116	233
Aug	-143	67	-126	-122	26	76	74	140	-81	115	164
Sep	-121	92	-100	-89	11	7	43	107	-20	99	44
Oct	-72	148	-41	-15	-24	-148	-28	31	17	63	-23
Nov	29	263	81	137	-95	-466	-174	-124	45	-12	-65
Dec	63	302	122	189	-120	-573	-223	-177	54	-37	-77
Annual	**-577**	**2105**	**-143**	**256**	**-490**	**-2681**	**-751**	**-71**	**-5**	**542**	**179**

[9] The Programmable Thermostat and "Other Multiple Rebates" measures were omitted due to a lack of statistical significance in the model

Three out of four of these measure combinations had a furnace fan installed as one of the rebates. When a participant had a Central AC unit installed together with a Furnace Fan, they showed the greatest annual savings among all measure combinations. However, if a Central AC system was the only rebate measure installed in a home, a customer experienced an increase in energy usage. Additionally each customer who had a Heat Pump unit installed showed an increase in energy use.

While most measure combinations showed an increase in annual usage, each showed monthly savings in several months. Each Central AC measure showed an increase in usage during the summer months but a decrease in usage in the winter. Conversely, Heat Pump measures showed increased usage in the winter months but decreased usage in the summer months. The Air Sealing rebate shows negligible annual savings at -5 kWh but exhibits monthly savings during the winter months. The Water Heater and Furnace Fan measures show monthly savings during the summer months.

Negative Savings

The billing analysis results prompted further investigation of the program processes to identify the cause of negative savings for certain measure groupings. This might be due to a number of customers fuel-switching from gas to electric or might be due to a first-time purchase of a Heat Pump or Central AC unit. If this is the case, it would be difficult to parse out savings from a Central AC rebate as those which used the rebate to upgrade an existing unit might save energy while first-time buyers would almost certainly use more energy. Another possible explanation could be an increase in energy consumption from installing a fully functional HVAC system.

According to the results of the Residential Appliance Saturation Survey the majority of Central Hudson customers use fuel oil or natural gas as the primary heating fuel. Participants were required to report the existing heating fuel as part of the application process. Further investigation of program application data suggests that a significant number of customers may have switched to electricity from other non-electric fuel sources to participate in the program.

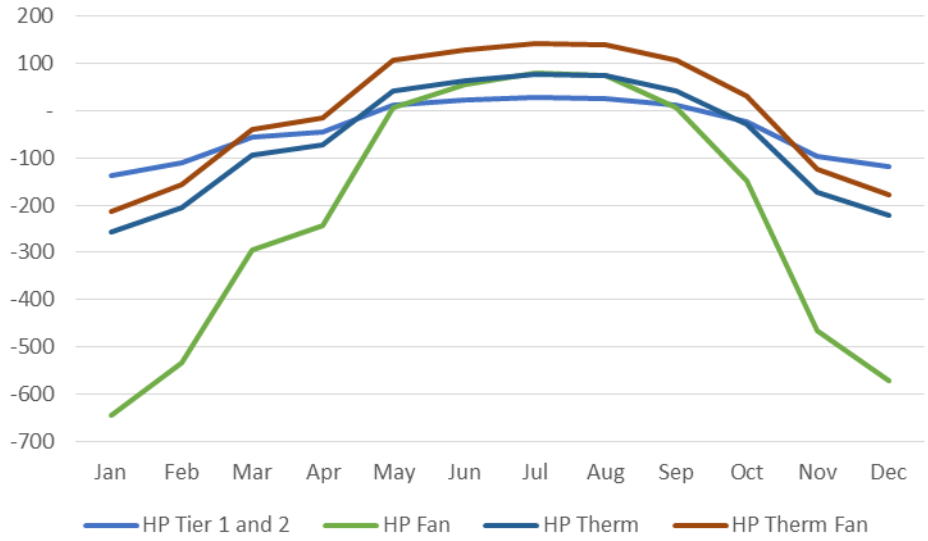
AEG requested the fuel switching data that was available electronically. Unfortunately, the fuel switching data is not available in electronic format prior to July 2012 due to administrative changes in program implementation. In July 2012 the program implementation responsibilities was shifted from Honeywell to ICF.

Analysis of the data from 2012 through 2015 showed that many customers switched heating fuels to participate in the program. Nearly 70% of the measures rebated since July 2012 were installed in households that switched to electric from natural gas or other non-electric fuel source. Since the fuel switching data is from after the 2010 through 2011, it could not be included in the regression model. Nevertheless, the prevalence of fuel switching in subsequent program years provides further plausibility that it occurred during the study period.

A likely explanation for the negative savings of several measure groupings is the increased electric usage among participants who switched to electric from a non-electric fuel source or first time buyers of central air conditioners. Negative savings is most prevalent in measure groupings that include a heat

pump. Analysis of the monthly savings of heat pump measures suggests that fuel switching may account to the negative savings.

Figure 2 Average Monthly Savings for Heat Pump Measure Combinations



The figure shows that negative savings is most prevalent during the fall and winter months, when the effects of fuel switching are expected to be most operative. All heat pump measures show positive savings during the May through September cooling season.

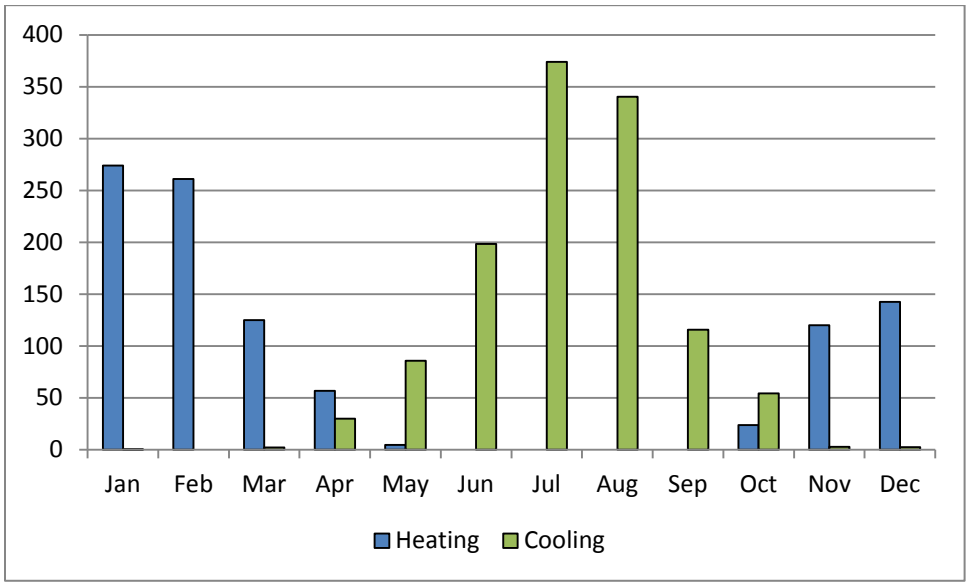
Overall, there was not sufficient data to conclusively identify and explain the occurrence of negative savings shown in the results of the billing analysis. As referenced previously in the report, possible explanations may include fuel switching, new equipment purchases for first time buyers, or the rebound effect of increased usage with a fully functional replacement system. However, AEG was unable to obtain sufficient or appropriately formatted data for inclusion in the billing analysis. For these reasons, AEG determined that the ex post analysis included in this evaluation report was more appropriate to estimate net savings.

Appendix A. HVAC Metering Study

AEG conducted a metering study to gain more information on the HVAC energy usage profiles of program participants. Participants were recruited to contribute to the study on an opt-in basis in response to a telephone survey. Prospective participants were offered a free programmable two-way Wi-Fi thermostat from Honeywell as an incentive to participate in the study. Study participants consented to anonymously relay runtime data to Honeywell, which was used to determine HVAC usage. Only three respondents agreed to participate in the metering study. Results of the study are anecdotal and are not intended to represent a statistically significant sample of program participants.

HVAC system runtime data was collected from study participants between October 2012 and January 2014 to ensure the data fully incorporated any seasonal changes. The Wi-Fi thermostats recorded total operating hours, not equivalent full load hours. The figure below shows the average monthly HVAC usage hours for all study participants in 2013. The overall annual averages are 740 hours for heating and 1,175 hours for cooling. The usage hour estimates are anecdotal and do not constitute a statistical representation of any population.

Figure 3 Average Monthly HVAC Usage Hours



Examining the results of each participant shows a wide variation in heating and cooling usage. The following figures show the results of each participant. Since only three customers were self-selected to participate in the study the results are strictly anecdotal and do not constitute a statistical representation of the Residential Electric HVAC program or the Central Hudson service territory.

Figure 4 Heating Hours by Participant

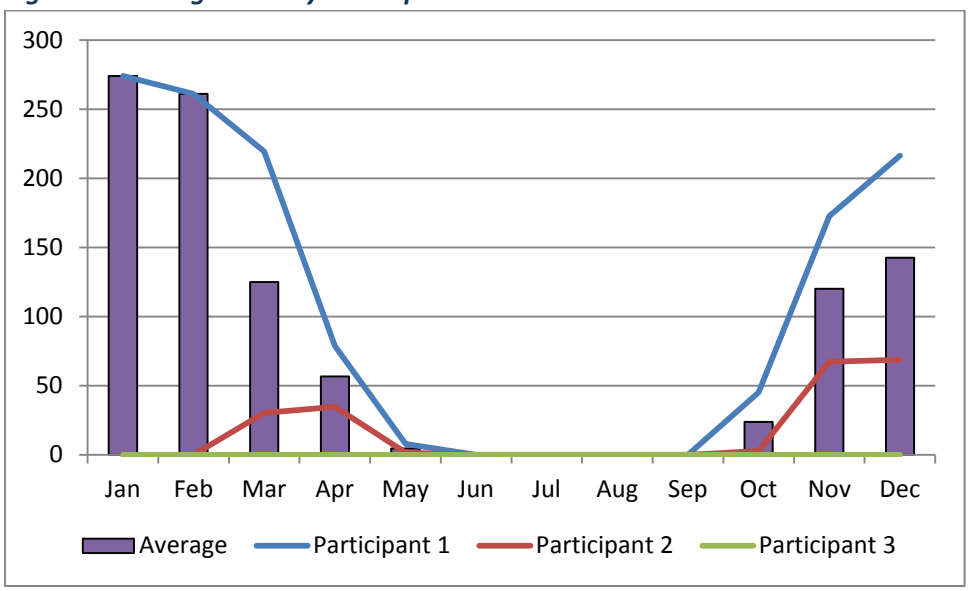
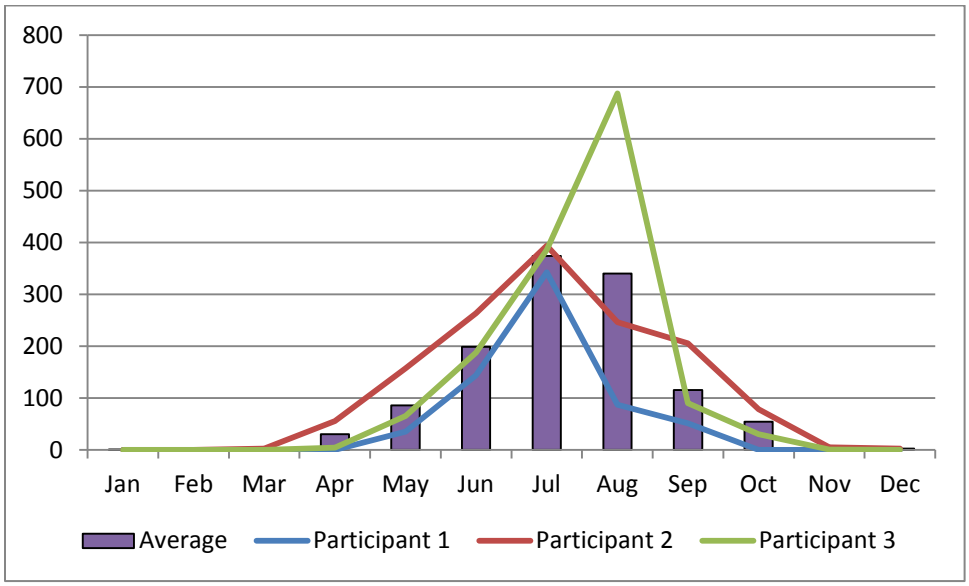


Figure 5 Cooling Hours by Participant



Appendix B. Participant Survey Guide

NOTE: To avoid duplication with interviews conducted in the Phase I Evaluation, check list of names prior to making phone call.

Customer Name	
Customer Phone Number	
Interviewer	

CONTACT RECORD		
Date	Time	Response

Response Codes

1. Busy Signal
2. No Answer
3. Call Back
4. Wrong Number (Cannot be Surveyed)
5. Refused (Cannot be Surveyed)
6. Interview – Incomplete (Cannot be Surveyed)
7. Interview Complete

Hello, I'm _____with Applied Energy Group. We are conducting a survey for Central Hudson Gas & Electric Company as part of Central Hudson's continual effort to improve its energy efficiency programs. According to our records, your household participated in the "Central Hudson Home Energy Savings Electric Rebate Program" in _____ {List Program Year as being either 2010 or 2011}.

The survey should only take about 10 minutes. The information you provide will be kept strictly confidential and will be used to improve Central Hudson's Energy Savings programs.

May I ask you a few questions about your participation?

1. Yes
2. No *(Determine if they would agree to another date/time: If "No," thank them for their time, and exit.)*

Do you recall participating in the Home Energy Savings Program offered by Central Hudson?

1. Yes
2. No *(The program provides rebates to customers who purchase energy efficient heating or cooling equipment in their homes. According to our records, your household purchased _____ {List measures rebated}. If they still do not remember,* ***Terminate the Interview.****)*

Participation Process

QP1. Do you recall the main reason you decided to participate? (**DO NOT READ** - ***Mark all that apply***)

1. Contractor recommended it
2. Needed a new heating/cooling system
3. Wanted to save money
4. Seemed like a good deal/offer from the utility
5. Wanted to save energy
6. Other (verbatim)

Customer Satisfaction

QS1. Please rate your satisfaction with the following program components on a five-point scale, where "5" means "Very Satisfied" and "1" means "Very Dissatisfied." How satisfied are you with the:

	Very Satisfied	4	3	2	Very Dissatisfied	Don't Know/ Refused
a) Enrollment process						
b) Performance of the new equipment obtained through the program, compared to your replaced equipment						
c) Contractor who performed the work						
d) Overall program experience						

Comments (verbatim)

Free Ridership

QF1a. Were you planning to purchase a new heating or cooling system with the EXACT SAME EFFICIENCY within three months before or after purchasing this equipment?

1. Yes
2. No (***Skip to QF1d***)
3. Don't Know/Refused (**DO NOT READ - *Skip to QF1d***)

QF1b. What factors prevented you from purchasing a system earlier? (**READ RESPONSES - *Mark all that apply***)

1. I did not have the money at that time.
2. I was not sure how long I would remain in my home.
3. I was not sure what type of system or brand to install.
4. I was not convinced I would save more.
5. I did not have a contractor I felt I could trust.
6. Other (verbatim)
7. Don't Know/Refused (**DO NOT READ**)

QF1c. Was one factor most significant?

1. Yes (list which factor)
2. No

3. Don't Know/Refused (**DO NOT READ**)

QF1d. How likely is it that you would have purchased and installed equipment with the EXACT SAME EFFICIENCY within 3 months of when you did participate in the program if the utility had NOT OFFERED the REBATE? (**READ RESPONSES**)

1. Very Unlikely
2. Somewhat Unlikely
3. Neither Likely nor Unlikely
4. Somewhat Likely
5. Very Likely
6. Don't Know/Refused (**DO NOT READ**)

Program Spillover Impacts

QS1a. Have you taken any other steps to reduce energy use in your home as a result of your participation in the Central Hudson Home Energy Savings Program?

1. Yes
2. No (***Skip to QS1c***)
3. Don't Know/Refused (**DO NOT READ - *Skip to QS1c***)

QS1b. Have you completed any of the following actions as a result of your participation in the program? (**READ RESPONSES - *Mark all that apply***)

____Shared your experience in the Home Energy Savings Program with your friends, neighbors and/or family members
____Replace incandescent light bulbs with compact fluorescent bulbs. If yes, approximately how many?
____Purchase Energy Star appliances. If yes, what type of appliance?
____Recycle a refrigerator or room air conditioner
____Install new energy efficient doors and/or windows in your home. If yes, approximately how many?
____Install / upgrade insulation in your home (walls, ceiling, attic)
____Insulate your water heater and/or install pipe insulation
____Can you think of any other energy savings actions you have taken, not mentioned in this list? **VERBATIM**

QS1c. *On a scale of 1-10 with 10 being very important and 1 meaning little importance, what influence did the program have in your decision to take additional energy efficiency actions in your home?*

(RECORD SCORE FROM 1-10)

Household / Dwelling Information

QD1. Which of the following best describes your residence? (**READ RESPONSES**)

1. Single-family, detached /owner occupied

2. Single-family, attached / owner occupied
3. Single-family / Renter occupied
4. Multi-family Building
5. Other, please specify
6. Don't Know/Refused (**DO NOT READ**)

QD2. Approximately how many square feet of living space is in your residence?

_____Ft2

Don't Know/Refused (**DO NOT READ**)

QD3. Approximately when was your home built?

1. Sometime before 1940
2. Between 1940 and 1959
3. 1960s
4. 1970s
5. 1980s
6. 1990s
7. 2000 or after
8. Don't Know/Refused (**DO NOT READ**)

QD4a. What is the main fuel used to heat your residence?

1. Natural Gas
2. Fuel Oil
3. Electricity
4. Propane / Other (List)
5. Don't Know/Refused (**DO NOT READ**)

QD4b. Do you use a back-up or secondary heating system?

1. Yes ***(Check from List)***
   __Wood Fireplace / Pellet Stove
   __Portable Electric Heater(s)
   __Kerosene / Other Fuel Oil
   __Solar
   __Other (verbatim)
2. No
3. Don't Know/Refused (**DO NOT READ**)

QD5a. Do you use a programmable thermostat to control the temperature of your home in the winter? *{The program rebated programmable thermostats}*

1. Yes
2. No ***(Skip to QD6)***
3. Don't Know/Refused (**DO NOT READ**) ***(Skip to QD6)***

QD5b. Can you give the approximate winter temperature settings on your thermostat during the following periods?

Weekdays (Monday – Friday):

1. 7 am through 5 pm: _____ (F or C)?
2. 5 pm through 11 pm: _____
3. After 11 pm to 7 am: _____

Weekends (Saturday – Sunday):

4. 7 am through 5 pm: _____ (F or C)?
5. 5 pm through 11 pm: _____
6. After 11 pm to 7 am: _____

QD6. What is the main fuel used to heat water in your home?

1. Natural Gas
2. Fuel Oil
3. Electricity
4. Solar Water Heating
5. Propane
6. Other (verbatim)
7. Don't Know/Refused (**DO NOT READ**)

QD7a. Which best describes how your home is cooled in the summer?

1. Central Air Conditioning System
2. 4 or More Room AC Units
3. 1 to 3 Room AC Units
4. Whole House Fan ***(Skip to QD9)***
5. Room Fans ***(Skip to QD9)***
6. No Cooling System in the Home ***(Skip to QD9)***

QD8a. Do you use a programmable thermostat to control the temperature of your home in the Summer? *{The program rebated programmable thermostats}*

1. Yes
2. No ***(Skip to QD9)***
3. Don't Know/Refused (**DO NOT READ**) ***(Skip to QD9)***

QD8b. Can you give the approximate summer temperature settings on your thermostat during the following periods?

Weekdays (Monday – Friday):

1. 7 am through 5 pm: _____ (F or C)?
2. 5 pm through 11 pm: _____
3. After 11 pm to 7 am: _____

Weekends (Saturday – Sunday):

4. 7 am through 5 pm: _____ (F or C)?
5. 5 pm through 11 pm: _____
6. After 11 pm to 7 am: _____

QD9. Is your residence occupied year-round?

1. Yes
2. No *If No, Approximately what percent of the year is it occupied? _____%*

QD10. I have one final set of questions concerning other energy savings actions you may have taken in your home during the last 1 to 3 years. I am going to read you a list of ways to cut energy use. Please let me know when I identify an action that you have taken to reduce energy use in your home sometime during the last 1 to 3 years: ***(Mark all that apply)***

1. ____Replaced incandescent light bulbs w/ compact fluorescent bulbs. If yes, approximately how many?
2. ____Purchased Energy Star-Rated appliances. If yes, what type of appliance?
3. ____Installed / upgraded insulation in your home (walls, ceiling, attic)
4. ____Installed new energy efficient doors and/or windows in your home. If yes, approximately how many?
5. ____Insulated your existing water heater and/or installed pipe insulation
6. ____Installed a solar water heating system or tankless water heater
7. ____Installed a home energy management system
8. ____Can you think of any other energy savings actions you have taken, not mentioned in this list? **VERBATIM**

Metering Study Supplement

Would you be willing to participate in a free metering study as a follow-up to this phone survey?

As a participant, Central Hudson will install a new programmable thermostat at your residence free of charge. You will be able to use an online portal or iPhone app to monitor your energy use and thermostat settings in real-time. There is no cost for your participation and you get to keep the thermostat after the conclusion of the study. Once the device is installed, Central Hudson will collect hourly data from your central air conditioning or heat pump system that will be used to improve energy efficiency programs in the future.

*[If they are **hesitant,** probe for reason(s) of reluctance. If concerns about use of data, mention all data is kept confidential. Also, mention that the T-Stat would be installed free of charge, on a date/time that is convenient for them.]*

Please answer the following yes/no questions to determine whether you are eligible to participate in the metering study:

1) Is your residence a single family home, townhome or condominium?
    a. Yes

b. No (END SURVEY - ineligible)

2) Do you have central air conditioning or a heat pump?

   a. Yes
   b. No (END SURVEY - ineligible)

3) Do you have electric baseboard heat or a geothermal heat pump?

   a. Yes (END SURVEY – ineligible)
   b. No

4) Is your air conditioning system made by Carrier Infinity?

   a. Yes
   b. No (END SURVEY - ineligible)

5) Do you currently have more than one thermostat and/or multiple zones at your house?

   a. Yes (END SURVEY - ineligible)
   b. No

6) Does the thermostat run only one air conditioning condenser or heat pump?

   a. Yes
   b. No (ineligible)

7) Do you have broadband internet and a wireless router?

   a. Yes
   b. No (ineligible)

8) Does anyone in the household have an iPhone?

   a. Yes
   b. No

9) Will you be living at your current residence for at least the next year?

   a. Yes
   b. No (ineligible)

Thank you for answering our questions and for agreeing to participate in the metering study. A customer service representative will be contacting you for set-up and installation. Please provide an email address where we will send you a link to sign up for the program.

Appendix C. Residential Electric HVAC Net-To-Gross Scoring Algorithms

Memorandum

To: Central Hudson Gas & Electric Company
From: Applied Energy Group, Robert Obeiter
Subject: Residential Electric HVAC Net-To-Gross Scoring Algorithms
Date: July 3, 2012

Free Ridership

Two survey questions were designed to determine customer free ridership. Each participant was assigned a value based on the probability that they are a free rider. The weighted mean of the participant probabilities provides an estimate of free ridership for the entire Home Energy Savings Central Electric Rebate Program. The following two tables present the participant probability by survey question.

Question 1: Were you planning to purchase a new heating or cooling system with the EXACT SAME EFFICIENCY within three months before or after purchasing this equipment?

Q2 Free Ridership Probability	Min	Max	Est.
Yes	0%	50%	25%
No	0%	0%	0%

Question 2: How likely is it that you would have purchased and installed equipment with the EXACT SAME EFFICIENCY within 3-months of when you did participate in the program if the utility had NOT OFFERED the REBATE?

Q1 Free Ridership Probability	Min	Max	Est.
Very Unlikely	0%	0%	0%
Somewhat Unlikely	10%	30%	20%
Neither Likely or Unlikely	30%	50%	40%
Somewhat Likely	50%	70%	60%
Very Likely	70%	90%	80%

Free ridership participant probabilities for question 1 and question 2 were averaged to get a free ridership estimate by customer surveyed, bound by 0% and 100%. The free ridership probability estimates are shown in the table below.

$$Free\ Ridership\ = \frac{Question\ 1\ +\ Question\ 2}{2}$$

Spillover

The following survey questions and scoring methodology is proposed for the calculation of program spill-over impacts.

Question SQ1: Since you participated in the Central Hudson program, have you taken any other actions to reduce energy use in your home? [1=Yes / 0 = No]

<u>Question SQ2</u>: [Ask only If Yes to SQ1]

Can you brief describe what EE measures/actions you took and from the following list I am going to read to you:

Measure/Action Taken (Measure/Action)	How Many?
Shared your experience in the Home Energy Savings Program with your friends, neighbors and/or family members	
Replace incandescent light bulbs w/ some compact fluorescent bulbs	
Replace all incandescent light bulbs w/ compact fluorescent bulbs	
Purchase Energy Star appliances	
Recycle a refrigerator or room air conditioner Install new energy efficient doors and/or windows in part of your home	
Install new energy efficient doors and/or windows in all of your home	
Install / upgrade insulation in your home (walls, ceiling, attic)	
Insulate your water heater and/or install pipe insulation	
Can you think of any other energy savings actions you have taken, not mentioned in this lsit?	

<u>Question SQ3</u>: {Only Ask If yes [=1] to Q1}: On a scale of 1-10 with 10 being very important and 1.0 meaning little importance, what influence did the program have in your decision to take additional EE actions in your home?

Scoring Method:

Spillover = If Question 1 is 'No,' then Spillover Score is <u>0%</u>

Else, If **Q1=1**, then Weighted Spillover Score =

SQ3 Score/10 (= Weighted (%) Spill-over Score)

We will then estimate kWh savings from spillover actions reported in the table above, *<u>for only those measure(s) for which savings estimates are available from the TRM</u>*, using the following calculations:

Estimated Weighted, Annualized Energy Savings from Spill-over Measure-j, for each respondent – i:

Spill-over Measure Savings $_{(participant\text{-}i,\ measure\text{-}j)}$ =

TRM kWh Savings $_{(measure\text{-}j)}$ * Weighted (%) Spill-over Score$_{(participant\text{-}i,\ measure\text{-}j)}$

Next, to develop the ***Spill-over Factor Adjustment***, we will sum over all estimates of program spill-over savings (measures and participants), and calculate the following ratio:

$$\frac{\sum \text{Spill-over Measure kWh Savings}_{(participant\text{-}i,\ measure\text{-}j)}}{\sum \text{Total kWh for EE Measures for } \textit{All} \text{ Survey Respondents}}$$

This ratio we define as, the ***Spill-over Adjustment Factor*** to be included in the net-to-Gross (NTG) Adjustment to Savings.

Note: This ratio should be a very, very small number (i.e. 1.0 <<<), as only a few respondents will most likely respond Yes (SQ1=1), which will then we weighted down by their 1-10 ranking in SQ3.

Appendix D. Spillover Calculation Summary

Table 21 Spillover Savings by Participant

Respondent ID	Net SO	Score	Gross SO	CFLs	Appliances	Refrigerator Recycle	Doors/Windows	Insulation	Pipe/WH insulation
1928588123	0	40%	0	0	0	0	0	0	0
1928518620	2,160	90%	2,400	1,081	147	1,005	0	167	0
1928416815	1,027	100%	1,027	594	0	0	0	167	265
1928318791	233	60%	388	324	0	0	64	0	0
1928218405	561	70%	801	324	147	0	64	0	265
1928000764	1,661	100%	1,661	1,081	147	0	0	167	265
1926879481	194	50%	388	324	0	0	64	0	0
1926695889	214	50%	427	216	147	0	64	0	0
1926588204	131	10%	1,312	1,081	0	0	64	167	0
1926573714	270	50%	540	540	0	0	0	0	0
1925762516	576	50%	1,152	0	147	1,005	0	0	0
1925558184	194	50%	388	324	0	0	64	0	0
1925373637	1,107	80%	1,383	0	147	1,005	64	167	0
1925240439	189	50%	378	0	147	0	64	167	0
1925185394	1,374	70%	1,963	810	147	1,005	0	0	0
1925109013	389	60%	649	270	147	0	64	167	0
1924359471	1,454	100%	1,454	810	147	0	64	167	265
1924333154	787	70%	1,125	810	147	0	0	167	0
1924282111	283	60%	471	324	147	0	0	0	0
1924249993	2,421	60%	4,036	2,702	0	1,005	64	0	265
1924197792	1,323	80%	1,653	648	0	1,005	0	0	0
1924007721	796	100%	796	648	147	0	0	0	0
Total	**17,343**	**n/a**	**24,392**	**12,914**	**1,914**	**6,029**	**703**	**1,505**	**1,327**
Average	**788**	**66%**	**1,109**	**587**	**87**	**274**	**32**	**68**	**60**

** Weighted average by gross spillover savings*

Table 22 Spillover Actions by Participant

Respondent ID	CFLs	Appliances	Refrigerator Recycle	Doors/Windows	Insulation	Pipe/WH insulation
1928588123	0	0	0	0	0	0
1928518620	20	1	1	0	1	0
1928416815	11	0	0	0	1	1
1928318791	6	0	0	1	0	0
1928218405	6	1	0	1	0	1
1928000764	20	1	0	0	1	1
1926879481	6	0	0	1	0	0
1926695889	4	1	0	1	0	0
1926588204	20	0	0	1	1	0
1926573714	10	0	0	0	0	0
1925762516	0	1	1	0	0	0
1925558184	6	0	0	1	0	0
1925373637	0	1	1	1	1	0
1925240439	0	1	0	1	1	0
1925185394	15	1	1	0	0	0
1925109013	5	1	0	1	1	0
1924359471	15	1	0	1	1	1
1924333154	15	1	0	0	1	0
1924282111	6	1	0	0	0	0
1924249993	50	0	1	1	0	1
1924197792	12	0	1	0	0	0
1924007721	12	1	0	0	0	0
Total	239	13	6	11	9	5
Average	11	0.59	0.27	0.50	0.41	0.23

Appendix E. Cost-Effectiveness Analysis

Cost-Effectiveness Methodology

Cost-effectiveness analysis compares the costs and benefits of efficient equipment with those of baseline (non-efficient) equipment. Cost-effectiveness analysis indicates whether the efficient technology(s) improve a customer's financial position, decreases overall energy costs to ratepayers, or raises society's well-being. A program is considered cost-effective if the TRC benefit-cost ratio is greater than 1.0. DPS has not required cost-effectiveness tests as part of EEPS evaluation studies and has not confirmed the assumptions and approaches in this analysis.

AEG analyzed the cost-effectiveness of the Residential Electric HVAC Program utilizing four standard cost-effectiveness tests taken from the California Standard Practices Manual.[10] Each test analyzes cost-effectiveness from a different perspective and answers a separate question:

- **Total Resource Cost Test (TRC)**: Comparison of program administrator and customer costs to utility resource savings. Will the total costs of energy in the utility service territory decrease?
- **Participant Cost Test (PCT)**: Compares customer costs and benefits of installing the measure. Will the participant benefit over the life of the measure?
- **Ratepayer Impact Measure (RIM)**: Measures the impact of the DSM program on utility rates if rates were to be adjusted to account for the program. Comparison of utility program costs and bill reductions associated with energy savings to supply-side resource benefits. Will customer rates increase?
- **Program Administrator Cost Test (Utility Cost Test)**: Comparison of program administrator costs to supply-side resource benefits. Will utility costs to save energy be less than utility costs to deliver the same amount of energy?

Results from the impact evaluation, utilizing IPMVP best practices, are utilized in the four cost-effectiveness tests taken from the California Standard Practices Manual.

BenCost, an updated version of a public domain model that AEG customized for Central Hudson, was utilized to perform the cost-effectiveness modeling. BenCost is an input-output model that calculates all four cost-effectiveness tests. Central Hudson specific inputs, including avoided costs, discount rates, participation rates and incentives were used to conduct the cost-effectiveness analysis. All program costs and benefits are discounted to present-day dollar values in order to accurately compare future benefits with current costs.

[10] The California Standard Practices Manual details cost-effectiveness guidelines and procedures for standardized cost-effectiveness evaluations.

Cost-Effectiveness Results

AEG conducted a cost-effectiveness analysis of the program using the results of the engineering and billing analysis. The program achieved a TRC ratio of 0.91 using the ex post analysis results. The table below shows the full cost-effectiveness results using the ex post analysis savings values.

Table 23 Cost-Effectiveness Results, Ex post analysis

Test	BCR	Net Benefits	Total Benefits	Total Costs
Total Resource Cost	0.91	($241,480)	$2,376,461	$2,617,941
Utility Cost	1.16	$330,906	$2,376,461	$2,045,555
Participant Cost	2.13	$1,742,038	$3,283,784	$1,541,746
Ratepayer Impact	0.55	($1,983,518)	$2,376,461	$4,359,979
Societal Cost	0.96	($102,801)	$2,515,141	$2,617,941