New Jersey's Clean Energy Program Residential HVAC Impact Evaluation and Protocol Review

WarmAdvantage™ and CoolAdvantage™ Programs

FINAL

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1. Executive Summary

This report provides an energy impact evaluation of New Jersey's Clean Energy Program's Residential HVAC programs – CoolAdvantage and WarmAdvantage Programs.

The purpose of this evaluation is twofold:

- To offer recommendations for revisions to the savings calculation Protocols so that, going forward, the calculations using these Protocols provide (more) accurate statements of savings accomplishments, and
- To provide a retrospective assessment of program accomplishment, as part of a due diligence review of past utility program effectiveness on behalf of ratepayers.

The billing analysis performed for this evaluation provides the retrospective assessment of the key program measures. It also provides an empirical basis for recommendations for the most important Protocol equation inputs.

1.1 Protocol Review

This report provides a review of the savings algorithms for Warm- and CoolAdvantage Programs. The review assesses the appropriateness of the savings equations and the input parameters provided in the 2007 Protocols. The review draws on findings on operational parameters from the billing analysis conducted for this evaluation on recent program participants, as well as using additional secondary source research.

Key recommendations include:

- Adopt the impact evaluation estimates of Equivalent Full Load Hours (EFLH) for heating and cooling, 727 and 501 hours, respectively.
- Re-evaluate the 2007 Protocol proper sizing and QIV factors. Going forward, these factors will determine the majority of program cooling related savings. The billing analysis supports a maximum energy savings factor (combined proper sizing and quality installation verification) of 9.2 percent of installed usage. Installation-related demand savings cannot be estimated from the billing analysis. However, Demand savings should not be greater than energy savings. In the absence of better evidence, the demand savings factor should also be set at 9.2 percent of installed demand.
- Adjust installation-related factors (proper sizing, QIV or duct sealing) to properly calculate savings from the estimated unit usage. Savings percentages from research

are measured with respect to units without quality installation verification. Percentages need to be adjusted to get the proper savings from the usage estimated by the Protocol algorithms which include the effects of these quality installation improvements.

- Further research the coincidence factor of participant units. Proper sizing and QIV can have mixed effects on peak loads at extreme temperatures. The program coincidence factor should accurately reflect the coincidence factor of CoolAdvantage units at peak temperatures.
- Replace typical furnace or boiler output capacity (91,000 Btu) with individual qualifying unit output capacity in the heating savings equation.
- Continue to update the typical replacement heating equipment AFUE values using previous methodology. Include information on market share of unit types, if possible.
- Lower baseline water heater usage in the water heating saving equation from 212 therms to 180 based on regional estimates of average water heating usage.
- The Warm- and CoolAdvantage rebate applications are designed well to collect the necessary data for program tracking and evaluation purposes. The challenge with collecting tracking data is getting the data recorded accurately in the field and then transferring it successfully into a well-designed database that captures all of the necessary program data. The Warm- and CoolAdvantage programs can improve substantially in this respect. Of particular importance is the capturing of QIV and right-sizing activity that takes place.
- QIV and right-sizing activity by contractors needs to be validated by the program.

1.2 Ex-post Impact Evaluation

The ex-post impact evaluation provides a retrospective assessment of program accomplishment using participant billing records to assess the estimates of savings produced by the Protocol algorithms. The outcomes include estimates of measure level usage and savings for the major measures. In addition, the impact evaluation provides useful information related to the first purpose of the report, recommendations toward the revision of the Protocols. The data provided by the utilities did not allow us to determine participant counts, measure counts or measure savings to compare to numbers published in annual reports. Thus, the due diligence review focuses on comparison of gross impact evaluation results with savings as defined by the 2007 Protocol savings equations.

1.2.1 Gross Impact Estimates

Table 1-1 presents the per-unit gross impacts for the primary heating and cooling measures from the Cool-and WarmAdvantage Programs. Cool-Advantage provides electric savings only. WarmAdvantage generates some electric savings through efficient furnace fans but this evaluation addresses only gas savings.

Table 1-1
2005-2006 Cool- and WarmAdvantage Ex-Post Per-Unit Gross Impacts

Program	Fuel	Measures	Source of Energy Savings	Impact
CoolAdvantage	Electric	Central air conditioning and heat pumps	Efficency, sizing and Installation	456 kWh
Warm Advantage	Gas	Furnaces and boilers	Efficiency	100 Therms

The gross cooling impact estimate includes both efficiency-related improvements as well as savings related to proper sizing and quality installation verification services required of contractors. The 456 kWh savings level reflects the standard-efficiency baseline SEER in effect at the time the installations took place (SEER 11). Also reflected in this savings value are a new recommended cooling EFLH and a new recommended level of installation-related savings, based on the findings of this evaluation.

The gross heating impact estimate is confined to efficiency-related improvements. The 100 therm savings level reflects two recommendations. There is a new heating EFLH estimate, and the new unit capacity is used for the baseline case rather than the, Protocol-defined "typical" unit capacity.

1.2.2 Cooling impact Estimates

The gross cooling impact estimates produced by this analysis are lower than the gross estimate indicated by the Protocols. In this case, we are applying the 2007 Protocols but assuming a baseline SEER of 11 as was the case during 2005-2006. The reduction in impacts has two different sources:

- The billing analysis found lower usage levels (and lower EFLH) among participants than assumed by the Protocols. This 17 percent reduction in estimated usage lowers the efficiency-related savings by 17 percent when the efficiency-related Protocol equations are applied.

- A combination of the billing analysis and secondary research indicate that expected savings due to Quality Installation Verification and proper sizing, as indicated by the Protocols, is inflated. The billing analysis evidence supports a more conservative level of savings for QIV/proper sizing of 8.4 percent. This is compared to the Protocol combined savings of 19.25 percent[1].

These two different sources of reduction result in an estimated gross cooling impact that is 41 percent lower than indicated by the Protocols. Table 1-2 compares the impact estimates derived from the Protocols to those developed for this impact evaluation. The table includes a range of possible QIV/proper sizing savings percentages. The final value for the impact evaluation was the middle savings percentage, 8.4 percent[2].

Table 1-2
Gross 2005/2006 CoolAdvantage Ex-Post Per-Unit Impact Estimates Baseline SEER=11

Source for Hour (EFLH) Estimate	Post-Program Cooling Usage (kWh)	Effective Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%)	Impact of Efficiency Improvement (kWh)	Combined QIV/Sizing Savings Percentage	QIV/Sizing Savings as Percentage of Usage	Impact of Proper Sizing and QIV (kWh)	Total CAC or Heat Pump Cooling savings (kWh)
Protocols	1,500	600		409	19.3%	23.8%	358	767
Impact Evaluation	1,252	501	17	341	0.0%	0.0%	0	341
					8.4%	9.2%	115	456
					19.3%	23.8%	298	640

Table 1-3 provides the program-level cooling impacts for central air conditioners and heat pumps. The gross per unit impact savings are the same as in Table 1-2 above except expressed in MWs. The program-level gross impacts for both the Protocol and ex-post impact evaluation reflect counts of units from the tracking data received from the utilities.

[1] Both estimates of QIV and proper sizing assume both actions took place for all participating units where appropriate. QIV and proper sizing, however, are difficult program measures to confirm, leaving the possibility that less than full program QIV and proper sizing takes place. Sources close to the program indicate that QIV and proper sizing were an active part of the program during the 2005-2006 period. They also indicate that the program's ability to confirm the activities was limited. It's worth noting that, going forward, additional steps have been added to the program implementation process to better confirm the results of QIV and proper sizing.

[2] QIV/Sizing savings percentages vs. Savings as a percentage of Usage are explained in section 3.1.2.1.

Table 1-3

Electric Impacts from Cooling Measures, Protocol Vs. Impact Evaluation

Source	Year	Per-Unit Impact (MWh)	Tracking Data Number of units*	Gross Impact (MWh)	(-) Free Ridership (MWh)	(+) Spillover (MWh)	Percentage of Gross Savings		Net Impact (MWh)
							Free Ridership	Spillover	
Protocol	2005	0.767	9,141	7,011					7,011
	2006		9,821	7,533					7,533
Impact Evaluation	2005	0.456	9,141	4,168	1,981	194	48%	5%	2,381
	2006		9,821	4,478	2,129	218		5%	2,567

* Count of units is from the tracking data provided to the evaluation by the utilities.

Table 1-3 also includes the effects of free ridership and spillover on program-level savings. The Protocols do not indicate individual free ridership and spillover levels, but do state that they have a net effect of zero[3]. For the Protocols, then, net impact equals gross impact. This impact evaluation produced independent estimates of free ridership and spillover. Free ridership and spillover estimates are more difficult and controversial than gross impact estimates. The relatively simple, self-report-based free ridership and spillover estimates derived for this evaluation indicate a much higher level of free ridership than spillover. If these estimates are incorporated into the program-level results, the net program impacts are further reduced relative to the Protocol estimate of net savings. It may be appropriate to use the estimates of free ridership and spillover developed in this study rather than the pre-existing Protocol assumption of 100 percent net-to-gross value.

The impact evaluation indicates a total reduction in estimated impacts of approximately 66 percent. The change in the QIV/proper sizing factor explains a 32 percent reduction relative to the gross Protocol impact estimate. The change in EFLH accounts for a 9 percent reduction. The combined free ridership/spillover estimate accounts for a 25 percent reduction. Thus, the largest piece of the reduction in cooling-related impacts is due to the change in the QIV/proper sizing factor. The combination of free-ridership and spillover also explains a large part of the reduction.

It's important to note that all of the results reported in this section assume a standard baseline of SEER 11 rather than the new Federal standard of SEER 13. Estimates for savings under the new Federal standards are reported in section 6.1.4.

[3] "the net of free riders and free drivers are assumed to be zero in the counting of units from direct program participation." p. 2. Protocols to Measure Resource Savings, December 2007

1.2.3 Heating impact Estimates

The gross heating impact estimates produced by this analysis are lower than the gross estimate indicated by the Protocols. The reduction in gross per-unit impact from 235 therms to 100 therms is caused by two factors:

- The existing Protocol equation artificially inflates savings by overstating the baseline unit capacity. The impact evaluation uses the more standard assumption of no change in unit capacity[4].

- A lower estimate of heating usage and Equivalent Full Load Hours (EFLH). The EFLH used to estimate heating impacts was derived from the billing analysis and is more consistent with secondary sources than the existing Protocol value.

Table 1-4
Gross WarmAdvantage Per-Unit Impacts, Protocol vs. Impact Evaluation

Source for Hour (EFLH) Estimate	Post-Program Usage (Therms)	Equivalent Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%, Hours)	Baseline Capacity	Impact Relative to Standard (Therms)
Protocols	860	965	[redacted]	91,000	235
Impact Evaluation	648	727	13	82,449	100

Table 1-5 provides the program-level heating impacts for furnaces and boilers. The gross per-unit impacts are the Table 1-4 values reported in MWs. The gross results for both the Protocol and the ex-post impact evaluation reflect counts of units from the tracking data received from the utilities. As with the cooling measures, the Protocols have net free ridership and spillover of zero.

[4] Section 3.2.1 discuss the equations used to estimate heating savings.

Table 1-5

Gas Impacts from Heating Measures, Protocol Vs. Impact Evaluation

Source	Year	Per-Unit Impact (1000 therms)	Tracking Data Number of units*	Gross Impact (1000 therms)	(-) Free Ridership (1000 therms)	(+) Spillover (1000 therms)	Percentage of Gross: Free Ridership	Percentage of Gross: Spillover	Net Impact (1000 therms)
Protocol	2005	0.235	9,658	2,270					2,270
	2006		11,363	2,670					2,670
Impact Evaluation	2005	0.100	9,658	966	434	122	45%	13%	654
	2006		11,363	1,136	511	136		12%	762

* Count of units is from the tracking data provided to the evaluation by the utilities.

As with the cooling measures, this impact evaluation produced independent estimates of free ridership and spillover. Free ridership and spillover estimates are more difficult and controversial than gross impact estimates. The relatively simple, self-report-based free ridership and spillover estimates derived for this evaluation indicate a much higher level of free ridership than spillover. If these estimates are incorporated into the program-level results the net program impacts are further reduced relative to the Protocol estimate of net savings. It may be appropriate to use the estimates of free ridership and spillover developed in this study rather than the pre-existing Protocol assumption of 100 percent net-to-gross value.

For 2006, the impact evaluation indicates a total reduction in estimated impacts of approximately 71 percent. The change in heating savings equation accounts for a 44 percent reduction relative to the gross Protocol impact estimate. The change in EFLH and the free ridership adjustment both account for a 14 percent reduction. Thus, the majority of the reduction in heating-related impacts is due to the correction of the faulty equation rather than analysis results produced by this evaluation.

2. Introduction

This report provides an evaluation of New Jersey's Clean Energy Program's Residential HVAC programs – CoolAdvantage and WarmAdvantage Programs. These programs provide rebates for the installation of energy efficient cooling, space heating and water heating measures. The programs calculate savings for these installations using the "New Jersey Clean Energy Program Protocols to Measure Resource Savings" (Protocols).[5]

This report has two functions:

1. To offer recommendations for revisions of the savings calculation Protocols so that going forward the calculations using these Protocols provide (more) accurate statements of savings accomplishments.
2. To provide a retrospective assessment of program accomplishment, as part of a due diligence review of past utility program effectiveness on behalf of ratepayers.

The second function is addressed with an ex-post impact evaluation. The ex-post impact evaluation was designed to support potential Protocol revisions as mandated by the first function. The impact evaluation focuses on the measures that generated the majority of the savings for the programs. The results produced by this impact evaluation provide key revisions to important Protocol equations. In addition to the direct impact evaluation input, KEMA engineers performed a review of Protocol equations and the recommended inputs.

2.1 Report Organization

Section 3 of this report is a review of the current 2007 Protocols. This review is developed from an engineering perspective using KEMA expertise and secondary sources. It also includes the recommendations based on the ex-post impact evaluation.

The remainder of the report presents the ex-post impact evaluation. Section 4 provides an overview of the evaluation process and a review of the methods employed for the impact evaluation. These include the billing analysis as well as the free ridership and spillover methodologies. Section 5 introduces all the data sources used for the analysis. Section 6

[5] There are two versions of the Protocols: *New Jersey Clean Energy Program Protocols, September 2004*, referred to here as the 2004 Protocols, and the *Revisions to September 2004 Protocols, December 2007*, hereafter the 2007 Protocols.

provides the results from the billing analysis and free ridership and spillover analyses. These results include *ex-post* impact estimates reflecting the success of the programs during the years 2005 and 2006. These results also provide the basis for further review and revision of the protocol equations.

3. Review of Protocols

The first priority of this report is to review the savings calculation Protocols. This review addresses two questions:

1. Is the Protocol equation appropriate for its designated purpose?
2. Are the input values used in the Protocol equations the best available estimates?

This section introduces all of the residential HVAC Protocol equations as they presently exist in the most recent version of the Protocols (1)[6]. These 2007 Protocols are a revised version of the 2004 Protocols of the same name. The revisions to the 2004 Protocols were driven, at least in part, by recommendations provided in the Energy Efficient Market Assessment of the New Jersey Clean Energy Program produced for the New Jersey Board of Public Utilities in 2006 (2).

The second priority of this report is the ex-post impact evaluation of program years 2005 and 2006. The impact evaluation is discussed in later sections of this report. Where possible, the results of the impact evaluation inform the recommended protocol revisions. We indicate, in the following protocols review section, if the impact evaluation is the basis for the recommended protocol revisions.

3.1 Residential Electric HVAC Protocol

3.1.1 Central Air Conditioner and Air Source Heat Pump Cooling Energy and Peak Demand Impact Algorithm

The energy usage and demand due to central air conditioners (CAC) are calculated using Equation 1 and Equation 2, respectively.

$$\Delta kWh_S = CAPY_Q * \left(\frac{1}{1000} \frac{kWh}{Wh} \right) * \left(\frac{1}{SEER_B} - \frac{1}{SEER_Q} \right) * EFLH_C \qquad \text{Equation 1}$$

$$\Delta kW_S = CAPY_Q * \left(\frac{1}{1000} \frac{kW}{W} \right) * \left(\frac{1}{EER_B} - \frac{1}{EER_Q} \right) * CF \qquad \text{Equation 2}$$

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[6] References in the Protocol review section are numbered and refer to the list of references at the end of the section on page 3-2.

The variable definitions, values, and sources for the equations are shown in Table 3-1.

Table 3-1
Variables for Equation 1 and Equation 2[7]

Variable		Description		Value	Source
ΔkWh_S	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
ΔkW_S	=	Peak kW impact from baseline efficiency to new efficiency	=		Result
$CAPY_Q$	=	Qualifying Unit Capacity, in Btu/hr	=		Tracking
$SEER_B$	=	Baseline SEER	=	13	Protocols
$SEER_Q$	=	Qualifying Unit SEER	=		Tracking
EER_B	=	Baseline EER	=	11.3	Protocols
EER_Q	=	Median Qualifying Unit EER	=	$(11.3/13)*SEER_Q$	Protocols
$EFLH_C$	=	Cooling Equivalent Full Load Hours	=	600	Protocols
CF	=	Coincidence Factor	=	70%	Protocols

The Protocol algorithms used to calculate energy and demand savings for CAC and air source heat pump cooling load are basic engineering equations. These equations measure only the impacts resulting from efficiency improvements. The 2004 Protocols used a similar equation that embedded a single factor into this basic equation to account for savings due to proper sizing and installation verification in addition to the efficiency savings. In the 2007 Protocol, the savings due to proper sizing and installation verification are estimated in separate algorithms.

[7] SEER and EER are ratings of the cooling performance for air conditioners and heat pumps. SEER provides a measure of average efficiency while EER measures efficiency at maximum load. SEER is the Btu of cooling output during a typical cooling-season divided by the total electric energy input in watt-hours during the same period. EER is the Btu of cooling output at maximum AC load divided by the watts of electrical power input.

Coincidence factor, in this context, is defined as the fraction of the customer's maximum AC load that occurs at the utility's peak.

Equivalent full load hours (EFLH) is the amount of time, expressed in hours, a unit runs at full load during a single year. This is in contrast to heating or cooling hours which is the number of hours during a year in which the unit runs for any portion of the hour.

Capacity and new unit SEER are values supplied by the program tracking data. Baseline SEER is set by the program and represents the SEER level above which the program offers rebates. The baseline SEER is set at 13 to adhere to new Federal standards (Federal Register)(3).

The baseline EER value was selected as 11.3 as an approximate industry average EER of a SEER 13 unit. The qualifying unit EER is then calculated by multiplying the qualifying $SEER_Q$ by the ratio of the baseline EER_B to $SEER_B$. In the absence of nameplate EER data, the estimation of qualifying unit EER_Q based on the qualifying unit $SEER_Q$ assumes a consistent relationship between SEER and EER across the baseline and qualifying units.

The current Protocols set cooling equivalent full load hours (EFLH) and coincidence factor (CF) at 600 hours and 70 percent, respectively. These values are the same as those in the 2004 Protocols. The cooling EFLH value references the Vermont Energy Investment Corporation. The reference also states that the value is consistent with Pepco and LIPA and conservative relative to ARI.

The CF is defined as the percent of AC full load in use at the time of the system peak. The references both in the Protocols and the Market Assessment do not appear to provide substantiation of this coincidence factor.

3.1.1.1 Discussion of Key Protocol Algorithm Inputs

Cooling EFLH and CF drive the energy and demand savings equations. They are essential inputs for determining energy and demand savings that are specifically relevant to the New Jersey programs. The sources for these values are not clearly documented. They do not appear to be either recent or New Jersey-specific.

The ex-post impact evaluation performed in conjunction with this review provides up to date and New Jersey-specific estimates of EFLH that can be used in the energy savings equation. The post-program cooling billing analysis provides an estimate of average cooling usage of 1,252 kWh. Using Protocol equations together with the actual $SEER_Q$ and capacity $CAPY_Q$ of the units in the program, this usage level indicates an EFLH estimate of 501 hours. The 90 percent confidence interval is plus or minus 17 hours. This is a strong statistical result well below the current Protocol value of 600 hours for cooling EFLH.

The billing analysis approach used in this evaluation to estimate EFLH does not provide any insight into the coincidence factor. In general, this factor is a function of hourly usage patterns and unit sizing. Direct load control program evaluations are a potential source for New Jersey specific estimates of CF. KEMA did an impact analysis of the PSE&G program in 2001 and, more recently, RLW gathered data from similar evaluations across PJM territory to develop deemed savings estimates for DLC programs. An estimate of average duty cycle at system peak temperature conditions would provide a good estimate of CF. While this approach would yield an estimate of CF based on New Jersey data, it would not account for proper sizing of CoolAdvantage units. Taking the proper sizing effect into account would increase CF compared to what was observed in the DLC evaluations. In the absence of further study, the CF of 70 percent is an adequate estimate of a New Jersey specific CF[8].

3.1.2 Energy and Demand Impact for Proper Sizing, QIV and Duct Sealing

This protocol was developed to account for energy and demand savings associated with proper sizing, quality installation verification (QIV) and duct sealing. Energy and Demand impacts for these practices are derived from post-program energy usage and peak demand. The separate calculation of savings for the first two of these practices is new in the 2007 Protocols. The duct sealing equation is altogether new in the 2007 Protocols. All three share the basic energy usage and demand equations. Energy usage is estimated as

$$kWh_Q = CAPY_Q * \left(\frac{1}{1000} \frac{kWh}{Wh} \right) * \frac{1}{SEER_Q} * EFLH_C \qquad \text{Equation 3}$$

Peak demand is estimated as

$$kW_Q = CAPY_Q * \left(\frac{1}{1000} \frac{kW}{W} \right) * \frac{1}{EER_Q} * CF \qquad \text{Equation 4}$$

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[8] ISO-NE uses a CF of 75 percent for seasonal peak hours. http://www.iso-ne.com/committees/comm_wkgrps/othr/drg/mtrls/DRG_SeasonalPeakHours_101906.ppt

Table 3-2
Variables for Equation 3 and Equation 4

Variable		Description		Value	Source
kWh_Q	=	Annual kWh post-program	=		Result
kW_Q	=	Peak kW post-program	=		Result
$CAPY_Q$	=	Median Qualifying Unit Capacity, in BTU	=		Tracking
$SEER_Q$	=	Median Qualifying Unit SEER	=		Tracking
EER_Q	=	Median Qualifying Unit EER	=	$(11.3/13)*SEER_Q$	Protocols
CF	=	Coincidence Factor	=	70%	Protocols
$EFLH_C$	=	Cooling Equivalent Full Load Hours	=	600	Protocols

These are the engineering equations used to describe cooling system energy usage. All the inputs for these equations are the same as those listed above for the energy and demand saving equations.

Impacts from proper sizing, kWh_P *and* kW_P, are estimated as a percentage proper sizing factor (PSF) of post-program cooling usage, kWh_Q and kW_Q. Therefore, the equations for proper sizing impacts are

$$kWh_P = kWh_Q * PSF \qquad \text{Equation 5}$$

and

$$kW_P = kW_Q * PSF \qquad \text{Equation 6}$$

The QIV impacts, kWh_V *and* kW_V, are derived from post-program usage less the impact of proper sizing.

$$kWh_V = kWh_Q * (1 - PSF) * QIF \qquad \text{Equation 7}$$

and

$$kW_V = kW_Q * (1 - PSF) * QIF$$ Equation 8

Finally, impacts from duct sealing , kWh_D and kW_D, are

$$kWh_D = kWh_Q * DuctSF$$ Equation 9

and

$$kW_D = kW_Q * DuctSF$$ Equation 10

Table 3-3
Variables for Equation 5, Equation 6, Equation 7, Equation 8, Equation 9, and Equation 10

Variable		Description		Value	Source
kWh_P	=	Annual kWh savings due to proper sizing	=		Result
kW_P	=	Peak kW savings due to proper sizing	=		Result
kWh_V	=	Annual kWh savings due to quality installation	=		Result
kW_V	=	Peak kW savings due to quality installation	=		Result
kWh_D	=	Annual kWh savings due to duct sealing	=		Result
kW_D	=	Peak kW savings due to duct sealing	=		Result
PSF	=	Proper Sizing Factor	=	5%	Protocols
QIF	=	Quality Installation Factor	=	15%	Protocols
DuctSF	=	Duct Sealing Factor	=	18%	Protocols

All three sets of energy and demand savings equations for installation-related improvements assume the installation of a qualifying unit. The rebate application indicates that only proper sizing and QIV are required for a qualifying installation. The duct sealing equation is new in the 2007 Protocol and appears to respond to recommendations in the Market Assessment review.

The role of duct sealing in the CoolAdvantage program is not clearly outlined in the program materials.

In the 2004 Protocols, proper sizing and QIV were combined in a single energy sizing factor (ESF). An ESF of 17 percent accounted for energy savings due to both proper sizing and QIV. It was embedded in the overall energy savings equations. The demand saving factor (DSF) of 7 percent was embedded in the demand savings equation.

The new proper sizing and QIV factors (PSF and QIF) for the 2007 Protocols, 5 and 15 percent, respectively, combine to create a total installation effect of 19.25 percent (5 percent + 15 percent * 95 percent). These two factors in combination are equivalent to the energy savings factor (ESF) from the 2004 Protocols. This number is applied to both qualified energy and demand savings so is also equivalent to DSF from the 2004 protocols. The 2007 Protocols provide a NEEP study (Titus, 2006, Appendix C) as a reference for the new proper sizing, QIV and duct sealing factors (4). The NEEP study only states the results from other work by Proctor, but does not provide a reference suitable for identifying the original source of the data.

3.1.2.1 Discussion of Key Protocol Algorithm Inputs

The new proper sizing and QIV savings equations produce two separate savings estimates for the two processes and do so separately from the energy efficiency savings estimate. In both respects this is a change from the 2004 Protocols. Separating the non-efficiency-related sources of savings is useful as it facilitates comparing the savings from efficiency with the savings from proper sizing and quality installation. This is particularly important given the rising importance of installation-related savings in the total program savings.

Separating the proper sizing and QIV factors is more challenging. The separate equations do not properly reflect the complex interaction between these two factors across the temperature spectrum. Furthermore, available research does not give a clear picture of savings levels for New Jersey. The same issues affect the installation-related demand savings.

Reviewing the history of the proper sizing and QIV savings equations is useful. The combined effect of the proper sizing and QIV savings terms in the 2007 Protocols is directly comparable to the single joint term in the 2004 Protocol, for both energy and demand savings. Because of this, it is possible to compare the magnitude of the 2004 Protocol factors with the corresponding combined factor effects from the 2007 Protocols. The energy savings factor increased from 17 percent in 2004 to a combined 19.25 percent in 2007. The demand savings factor increased from 7 percent in 2004 to 19.25 percent in 2007.

The original 2004 Protocol values of 17 and 7 percent for energy and demand savings, respectively, were based on the 1999 Neme, et al. ACEEE report to the EPA (5). The Market Assessment review of the 2004 Protocols recommended lowering the combined energy and demand factors to 2.9 percent. As discussed above, the much higher 2007 Protocol values come from a more recent source but are not verifiable because the original source is insufficiently referenced.

With regards to energy savings, extensive field measurements in California reported by Mowris, *et al.* put QIV-related energy savings at a maximum of 8.4 percent for the general new unit population (6).

Recent research by Wirtshafter, et al in New England raises questions about the efficacy of quality installation programs in general. The article also specifically highlights the challenge of assigning demand savings without knowing capacity relative to true peak conditions (7). Quality installation makes the unit perform more efficiently. The unit will reach 100 percent duty cycle at a higher temperature than if it was not properly installed. However, if the temperature is high enough that the quality installed unit is at 100 percent duty cycle, then there are no quality installation-related demand savings. Wirtshafter's research suggests because of New England's combination of extreme peak day temperature combined with relatively low design condition temperature, there is no peak savings for QIV for a properly sized unit in the New England area.[9] The possibility of similar conditions must be considered for New Jersey.

These findings raise questions regarding the suitability and accuracy of the values assigned for the proper sizing and QIV factors in the 2007 Protocol. The magnitude of the QIV factor appears high for either energy or demand savings, but particularly so for demand savings. Furthermore, the use of a single factor level for energy and demand savings does not reflect the expected lower levels of savings at the higher duty cycles consistent with peak conditions.

Completely separate from the appropriate magnitude of values for proper sizing and QIV factors, the factors appear to be misapplied. QIV and sizing savings percentages from the literature represent the reduction in usage from the starting point of improperly installed unit usage. It is not correct to apply these percentages to the usage calculated using the Protocol

[9] The work found that, during peak periods, some units properly sized according to local Manual J specifications were effectively undersized. They would therefore run continuously in an attempt keep up with the peak load. The gains associated with QIV will not alleviate this situation. Some of Wirtshafter's sample was in New York.

equations which represents usage after proper sizing and installation. By doing this the program is understating QIV savings.

The proper combined ESF percentage, adjusted to be in terms of the available Protocol usage estimate, is calculated using the equation

$$ESF= ESF_{prop} /(1-ESF_{prop}) \qquad \text{Equation 11}$$

Where ESF_{prop} is the proposed savings percentage relative to improperly installed units and ESF is the factor to apply to the usage of properly installed units to calculate the appropriate amount of savings. For example, the California estimate of QIV-related savings, 8.4 percent, represents 9.2 percent of the usage of a properly installed unit.

The billing analysis performed for the *ex-post* impact evaluation provides only partial support for installation-related energy savings at any level. The true test of the installation savings comes from the pre-post billing analysis and requires assumptions regarding the SEER of the existing unit. (See section 4.1.1.) With reasonable assumptions of the existing unit SEER and replaced unit degradation, the pre-post billing analysis indicates combined installation and sizing-related impacts well below either the 2004 Protocol ESF value of 17 percent or the 2007 Protocol ESF of 19.25 percent. The estimate of 8.4 percent savings (9.2 percent of installed usage) from the Mowris research is more realistic given the billing model results.

We recommend using 9.2 percent of installed saving as the ESF value combining proper sizing and QIV. In the absence of better estimates, the same level should be used for the DSF value. Demand savings is expected to be smaller than energy savings, as it was in the 2004 Protocols. With the lower recommended ESF, DSF should be no higher than that same level.

Finally, the increase in the standard efficiency baseline for 2007 has the effect of lowering the efficiency-related savings for the CoolAdvantage Program. Even with the lower recommended installation-related savings, these proper installation factors are likely to be bigger than the efficiency-related savings generated by the program. With proper sizing and QIV savings driving the program results, there would be substantial value to field research in New Jersey to determine how effective the proper sizing and QIV aspects of the program are and set appropriate levels of savings for the New Jersey air conditioning market.

3.1.3 Energy and Demand Impact for Maintenance

Energy and Demand impacts due to proper maintenance are calculated using a similar methodology as proper sizing and QIV. Savings are a percentage of existing energy usage and peak demand. Since the impact for maintenance is based on existing equipment, we have evaluated this protocol separately. The basic equations follow.

Energy usage savings are estimated as

$$kWh_M = CAPY_M * \left(\frac{1}{1000}\frac{kWh}{Wh}\right) * \frac{1}{SEER_M} * EFLH_C * MF$$ Equation 12

Peak demand savings are estimated as

$$kW_M = CAPY_M * \left(\frac{1}{1000}\frac{kW}{W}\right) * \frac{1}{EER_M} * CF * MF$$ Equation 13

Table 3-4
Variables for Equation 12 and Equation 13

Variable		Description		Value	Source
kWh_M	=	Annual kWh post-program savings	=		Result
kW_M	=	Peak kW post-program savings	=		Result
$CAPY_M$	=	Capacity of unit having maintenance performed, in Btu/hr	=		Tracking
$SEER_M$	=	Assumed SEER of unit having maintenance performed	=	10	Protocols
EER_M	=	Assumed EER of unit having maintenance performed	=	$(11.3/13)*SEER_M$	Protocols
CF	=	Coincidence Factor	=	70%	Protocols
MF	=	Maintenance Factor	=	10%	Protocols
$EFLH_C$	=	Cooling Equivalent Full Load Hours	=	600 hours	Protocols

These are the engineering equations used to describe cooling system energy usage. Capacity and new unit SEER are values supplied from the program tracking data. The assumed SEER of 10 for a unit having maintenance performed is based on data in the Federal Register (3).

The maintenance equation is new in the 2007 Protocol and appears to respond to recommendations in the Market Assessment review. The role of maintenance in the CoolAdvantage program is not clearly outlined in the program materials. The 2007 Protocols provide a NEEP study (4) as a reference for the new proper maintenance factor. The NEEP study only states the results from other work by Proctor, but does not provide a reference suitable for identifying the original source of the data.

3.1.4 Heating Energy Impact for Air Source Heat Pumps

The Protocol algorithm used for energy impacts for air source heat pump heating is

$$\Delta kWh_{S(HEAT)} = CAPY_Q * \left(\frac{1}{1000} \frac{kWh}{Wh} \right) * \left(\frac{1}{HSPF_B} - \frac{1}{HSPF_Q} \right) * EFLH_H \qquad \text{Equation 14}$$

Table 3-5
Variables for Equation 14[10]

Variable		Description		Value	Source
$\Delta kWh_{S(HEAT)}$	=	Annual kWh savings from baseline efficiency to new efficiency	=	Result	Result
$CAPY_Q$	=	Median Qualifying Unit Capacity, in Btu/hr	=	Tracking	Tracking
$HSPF_B$	=	Baseline Heating Seasonal Performance Factor	=	7.7	Protocols
$HSPF_Q$	=	Qualifying Unit Heating Seasonal Performance Factor	=	Tracking	Tracking
$EFLH_H$	=	Heating Equivalent Full Load Hours	=	2250 hours	Protocols

This is a basic engineering equation used to describe heat pump heating energy impacts. Capacity and new unit $HSPF_Q$ are values obtained from the program tracking data. Baseline

[10] HSPF (heating seasonal performance factor) is a measure of average heat pump heating efficiency similar to SEER as a measure of cooling efficiency.

$HSPF_B$ is set by the program and represents the HSPF level above which the program provides rebates. The program threshold HSPF is set at 7.7 to adhere to Federal standards.

3.1.4.1 Discussion of Key Protocol Algorithm Inputs

The heat pump EFLH is substantially higher than the 2007 Protocol EFLH for gas furnaces and our lower recommended EFLH based on the ex-post impact evaluation. In general, for heating units of similar capacity and efficiency, there is no engineering-based reason to expect heat pumps to have a greater EFLH than furnaces or boilers. In particular, an increase in EFLH should not be used to compensate for poor heat pump performance at very cold temperatures.

Air source heat pumps have limited applicability in areas with temperatures below -10°C. It is unlikely that heat pumps are installed in parts of New Jersey that commonly experience these kinds of temperatures. If heat pumps are used at temperatures below -10°C, they are usually backed up with electric resistance heating. Under these circumstances, the efficiency would be lowered, but EFLH would not be affected.

The impact evaluation provides an appropriate value for $EFLH_H$ based on the gas billing regression results. Efficiencies do not need to be adjusted unless the program believes sufficient numbers of air source heat pumps are being installed in areas with extreme cold temperatures.

The 2004 Protocols for heat pumps included a savings term related to proper sizing and installation. This term has been eliminated in the 2007 Protocol. The current Protocol calculates savings based only on the difference in efficiency between a baseline unit and a high efficiency unit.

3.1.5 Energy Impact for Ground Source Heat Pumps

The Protocol algorithms used for cooling and heating energy impacts for ground source heat pumps are

$$\Delta kWh_{S(COOL)} = CAPY_Q * \left(\frac{1}{1000} \frac{kWh}{Wh} \right) * \left(\frac{1}{SEER_B} - \frac{1}{EER_G * GSER} \right) * ELFH_C \qquad \text{Eq. 15}$$

$$\Delta kWh_{S(HEAT)} = CAPY_Q * \left(\frac{1}{1000} \frac{kWh}{Wh} \right) * \left(\frac{1}{HSPF_B} - \frac{1}{COP_G * GSOP} \right) * ELFH_H \qquad \text{Eq. 16}$$

and

$$\Delta kW_S = CAPY_Q * \left(\frac{1}{1000} \frac{kW}{W} \right) * \left(\frac{1}{EER_B} - \frac{1}{EER_G * GSPK} \right) * CF \qquad \text{Eq. 17}$$

Table 3-6
Variables for Eq. 15, Eq. 16, and Eq. 17[11]

Variable		Description		Value	Source
$\Delta kWh_{S(COOL)}$	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
$\Delta kWh_{S(HEAT)}$	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
ΔkW_S	=	Peak kW post-program savings	=		Result
$CAPY_Q$	=	Median Qualifying Unit Capacity, in Btu/hr	=		Tracking
$SEER_B$	=	Baseline Unit SEER Factor	=	7.7	Protocol
$HSPF_B$	=	Baseline Unit Heating Seasonal Performance Factor	=		Tracking
EER_B	=	Energy Efficiency Ratio of the Baseline Unit	=	11.3	Protocol
EER_G	=	Energy Efficiency Ratio of Ground Source Heat Pump	=		Tracking
COP_G	=	Coefficient of Performance of Ground Source Heat Pump	=		Tracking
GSER	=	Conversion factor to calculate SEER from EER_G	=	1.02	Protocol
GSOP	=	Conversion factor to calculate HSPF from COP_G	=	3.413	Protocol
GSPK	=	Conversion factor to convert EER_G to EER for comparison	=	0.8416	Protocol

[11] Coefficient of Performance (COP) is a measure of heat pump heating efficiency at a specific temperature, usually 47° F.

Variable		Description		Value	Source
CF	=	Coincidence Factor	=	70%	Protocol
$EFLH_C$	=	Cooling Equivalent Full Load Hours	=	600 Hours	Protocol
$EFLH_H$	=	Heating Equivalent Full Load Hours	=	2250 Hours	Protocol

These engineering equations have the same basic form as the efficiency savings equations discussed previously. Capacity, new unit SEER, and ground source heat pump EER and COP are values supplied from the program tracking data. Standard SEER and EER are set by the program as previously discussed. Values for CF, $EFLH_C$ and $EFLH_H$ were also previously addressed.

The GSER is a necessary conversion factor. The GSER calculates the SEER value from the EER. The values for GSOP and GSPK are also necessary conversion factors. The GSOP converts COP to HSPF and is a basic engineering conversion. The GSPK creates an EER value for the ground source heat pump that is consistent with an EER of a comparably sized air cooled condenser.

3.1.5.1 Discussion of Key Protocol Algorithm Inputs

The 2007 Protocols were not revised from the 2004 Protocols for this measure. The Market Assessment review of the 2004 Protocols stated the equations and values for GSER, GSOP, and GSPK were reasonable base on the best available information. We see no reason to change this conclusion.

We believe both the heating and cooling Equivalent Full Load Hours ($EFLH_H$, $EFLH_C$) defined in the 2007 Protocol are high. The heat pump $EFLH_H$, in particular, is substantially higher than the $EFLH_H$ assigned for gas savings. For heating units with the same output capacity, there is no engineering-based explanation for heat pump EFLH to differ from a furnace-based EFLH. For ground source heat pumps, this is the case regardless of extreme cold temperatures.

The impact evaluation provides an appropriate value for both furnace and heat pump $EFLH_H$.

3.1.6 Energy Impact for Ground Source Heat Pump Desuperheater

The Protocol algorithms used for energy impacts for ground source heat pump desuperheaters are

$$\Delta kWh_S = EDSH \quad \text{Equation 18}$$

and

$$\Delta kW_S = PDSH \quad \text{Equation 19}$$

Table 3-7
Variables for Equation 18 and Equation 19

Variable		Description		Value	Source
ΔkWh_S	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
ΔkW_S	=	Peak kW post-program savings	=		Result
EDSH	=	Assumed Savings per desuperheater	=	1842 kWh	Protocols
PDSH	=	Assumed peak demand savings per desuperheater	=	0.34 kW	Protocols

Desuperheaters use excess heat generated by the ground source heat pump to heat water for household use. They cannot be the sole source of water heat as the heat pump must be running to produce hot water for a household. The desuperheater will produce savings by reducing water heating by the other source of hot water. These savings are fixed values that have been estimated by VEIC based on assumptions of PEPCo. We do not know the basis of the estimates.

3.1.6.1 Discussion of Key Protocol Algorithm Inputs

These algorithms assume that water heat is provided by an electric water heater. While it is less likely that a heat pump would be installed in a house with gas water heat, the water heat fuel should be confirmed. Similar algorithms could be developed for desuperheater gas savings if necessary.

3.1.7 Energy Impact for High Efficiency Furnace Fan

The Protocol algorithms used for energy impacts for high efficiency furnace fans are

$$\Delta kWh_{S(HEAT)} = CAPY_T * EFLH_H * \left(\frac{1therm}{100{,}000BTU}\right) * FFS_{HT} \qquad \text{Equation 20}$$

and

$$\Delta kWh_{S(COOL)} = FFS_{CL} \qquad \text{Equation 21}$$

Table 3-8

Variables for Equation 20 and Equation 21

Variable		Description		Value	Source
$\Delta kWh_{S(Heat)}$	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
$\Delta kWh_{S(Cool)}$	=	Annual kWh savings from baseline efficiency to new efficiency	=		Result
$CAPY_T$	=	Typical Unit Capacity, in Btu/hr	=		Tracking
FFS_{HT}	=	Furnace Fan Savings (Heating Mode)	=	0.5 kWh/therm	Protocols
FFS_{CL}	=	Furnace Fan Savings (Cooling Mode)	=	105 kWh	Protocols
$EFLH_H$	=	Equivalent Full Load Hours (Heating)	=	965 hours	Protocols

These algorithms are new in the 2007 Protocol. Although the forms of the two algorithms are different, the algorithms as defined are based on the research available and will provide reasonable savings estimates. For clarity and to eliminate confusion, we recommend revising the units on FFS_{HT} from kWh to kWh/therm. To further reduce potential confusion, we recommend revising the variable names to Heating Fan Savings (HFS) and Cooling Fan Savings (CFS). Users could confuse the two FFS values which would cause dramatically over or understated savings. Finally, we recommend revising the EFLH to be consistent with the $EFLH_H$ defined in other sections.

3.2 Residential Gas HVAC Protocol

3.2.1 Gas Savings for Space Heat

The Protocol algorithms used for energy impacts for gas fired furnaces are

$$\Delta TH_S = \left[\left(\frac{CAPY_T}{AFUE_B}\right) - \left(\frac{CAPY_Q}{AFUE_Q}\right)\right] * \left(\frac{1therm}{100{,}000Btu}\right) * EFLH_H \qquad \text{Equation 22}$$

$$\Delta TH_{S(DS)} = CAPY_T * EFLH_H * DuctSF_H * \left(\frac{1therm}{100{,}000Btu}\right) \qquad \text{Equation 23}$$

$$\overline{TH}_Q = EFLH_H * \left(\frac{1therm}{100{,}000Btu}\right) * \left(\frac{\overline{CAPY}_Q}{\overline{AFUE}_Q}\right) \qquad \text{Equation 24}$$

and

$$EFLH_H = \overline{TH}_Q * \left(\frac{100{,}000Btu}{1therm}\right) * \left(\frac{\overline{AFUE}_Q}{\overline{CAPY}_Q}\right) \qquad \text{Equation 25}$$

Table 3-9

Variables for Equation 22, Equation 23, Equation 24, and Equation 25[12]

Variable		Description		Value	Source
ΔTH_S	=	Annual therm savings from standard efficiency to new efficiency	=		Result
$\Delta TH_{S(DS)}$	=	Annual therm savings from duct sealing	=		Result
$\overline{TH}_Q$	=	Average annual heating use, in therms	=	659 therms	EIA
$CAPY_T$	=	Output capacity of typical heating unit, in Btu/hr	=	91,000 Btu/hr	Protocols

[12] AFUE (annual fuel utilization efficiency) is the measurement of how efficiently a gas furnace or boiler will operate over an entire heating season.

Variable		Description		Value	Source
$CAPY_Q$	=	Output capacity of qualifying heating unit, in Btu/hr	=		Tracking
$AFUE_B$	=	Annual Fuel Utilization Efficiency of baseline unit (Furnace)	=	80%	Protocols
		Annual Fuel Utilization Efficiency of baseline unit (Boiler)	=	83%	Protocols
$AFUE_Q$	=	Annual Fuel Utilization Efficiency of qualifying unit	=		Tracking
$EFLH_H$	=	Equivalent Full Load Hours (Heating)	=	965 hours	Protocols
$DuctSF_H$	=	Assumed Gas Savings due to duct sealing	=	13%	Protocols
$\overline{AFUE}_Q$	=	Average furnace or boiler AFUE	=	Undefined	Protocols
$\overline{CAPY}_Q$	=	Average furnace or boiler output capacity	=	Undefined	Protocols

These are basic engineering equations used to describe the gas heating impacts and usage. Output capacity and annual fuel utilization efficiency (AFUE) of new units are obtained from the program tracking data. Baseline annual fuel utilization efficiency is set by the program as 80% for furnaces and 83% for boilers.

The heating Equivalent Full Load Hours value for the 2007 Protocols is 965 hours. The 2004 Protocols used a different heating savings equation based on therms. For the 2004 Protocol equation, the primary input was 965 therms. The same source is listed in both Protocols. It appears the equations and units were updated but the value remained the same. If, by pure coincidence, the hours and therms from the same source are identical, a note to that effect should be added. In the absence of this coincidence, it is of particular importance to update the heating EFLH estimate.

The 2007 Protocols provide a NEEP study (4) as a reference for the duct sealing factor. The NEEP study only states the results from other work by Proctor, but does not provide a reference suitable for identifying the original source of the data.

The value for average annual heating use was obtained from Energy Information Administration data (8). The average annual heating use ($\overline{TH}_Q$), AFUE ($\overline{AFUE_Q}$) and average output capacity ($\overline{CAPY_Q}$) have no impact on the analysis and could be eliminated.

3.2.1.1 Discussion of Key Protocol Algorithm Inputs

The heating EFLH value provided in the Protocols appears to be high and may, in fact, be an incorrect value transferred from the 2004 Protocols. Regardless, the Market Assessment considered the 2004 Protocol estimate of 965 therms high based on the number of households in New Jersey with gas heat and annual residential gas usage in New Jersey. The Market Assessment estimated heating therms at 676 for 1999 and from this provided an estimate of EFLH of 593 hours.

The impact evaluation portion of this analysis provides an estimate of EFLH based on program data. Based on the post-program billing analysis, average annual heating usage was estimated at 648 therms for a typical weather year. Using Protocol equations, this level of usage indicates an EFLH of 727 hours. This value reflects the specific usage characteristics of program participants, with normal-year heating degree days. We recommend using the EFLH from the ex-post impact evaluation.

In the new 2007 Gas savings equation, there appears to be a combination of mismatched recommendations from the Market Assessment. The Market Assessment recommended the use of a different input to the old algorithm while it also recommended the adoption of a different algorithm altogether. The 2007 Protocol gas savings equation combines both of these recommendations despite the fact that it is clear the two recommendations were never intended to be combined

The new algorithm recommended by the Market Assessment is appropriate without the additional change. The change, the inclusion of a separate baseline capacity in the equation is problematic. The purpose of a separate baseline capacity is to capture a change in capacity due to the program. This would be a worthy goal if there was evidence that the program was driving participants to either increase or decrease their unit capacities. If there is such evidence, a better approach must be used than the mismatched 2007 gas savings algorithm approach. The Protocols baseline capacity is approximately 10 percent greater than the average capacity of furnaces being installed by the program. This has the effect of assuming downsizing on a large number of units. The WarmAdvantage Program has no proper sizing agenda and there is no other indication that downsizing of this magnitude is actually taking place. As the impact evaluation results show, the effect on estimated savings is substantial.

We recommend again, as was recommended originally when the 2007 algorithm was proposed, that the installed unit capacity be used for the baseline unit capacity as well as the newly installed unit. Thus, in the equation above, $AFUE_B$ is the same as $AFUE_Q$ rather than having predetermined input values.

The standard furnace and boiler AFUEs used by the Protocols reflect the average AFUE of available models in 2003. It is appropriate that these baseline AFUEs reflect the AFUE of standard installations. If market share information is available, it should be used to appropriately weight available models' AFUE to get the average installed unit AFUE. This approach has the advantage of being easily updated over time.

3.2.2 Gas Savings for Water Heaters

The Protocol algorithms used for energy impact for gas water heaters are

$$\Delta GS_S = \left(\frac{EF_Q - EF_B}{EF_Q} \right) * BWHU \quad \text{Equation 26}$$

and

$$EF_B = 0.67 - (0.0019 * GC) \quad \text{Equation 27}$$

Table 3-10
Variables for Equation 26 and Equation 27

Variable		Description		Value	Source
ΔGS_S	=	Annual gas savings from baseline efficiency to new efficiency	=		Result
EF_Q	=	Energy Factor of the qualifying energy efficient water heater	=		Tracking
EF_B	=	Energy Factor of the baseline water heater	=		Result
BWHU	=	Annual Baseline Water Heater Usage, in therms	=	212 therms	Protocols
GC	=	Gallon capacity of water heater	=		Tracking

These are the engineering equations used to describe the gas water heater energy impact. Gallon capacity and energy factor of the qualifying energy efficient water heater are values obtained from the program tracking data. The 2007 Protocol baseline water heater usage was updated to 212 therms based on data provided in the Federal Register (9). Assuming this annual usage, a 40 gallon tank, a baseline energy factor or 0.59 and the minimum qualifying energy factor for the program of .62, the impact would be 7.5 therms annually. These size and efficiency values reflect the median values for program participants. Larger size tanks and efficiency levels beyond the minimum levels set by the program will generate greater savings.

3.2.2.1 Discussion of Key Protocol Algorithm Inputs

The update to the 2007 Protocols baseline water heater usage was based on national averages rather than regional estimates. The 2001 Residential Enduse Consumption Survey from the Energy Information Administration estimates average water heating usage at 180 therms for the middle Atlantic and Northeastern states (10). This value provides a more conservative, regionally based estimate of water heating usage.

3.3 Protocol Measure Life Review

This section provides a review of Protocol measure lives for the Warm- and CoolAdvantage programs. The measure life, or estimated useful life (EUL), represents the average number of years a measure remains in place generating savings for the program. We compare the 2007 Protocol EULs to EULs from two different sources.

3.3.1 Estimated Useful Life

KEMA consulted two secondary sources for measure EULs to compare with the 2007 Protocol EULs. The first source was the Database for Energy Efficiency Resources (DEER) from the California Energy Commission and the California Public Utility Commission, recently updated for 2008 (11). Generally recognized as the most comprehensive resource for values like EULs and deemed savings estimates, DEER provides EULs for energy efficient measures installed in California. The second source we used was the ISO-NE Forward Capacity Market Reference Document produced in 2007 by GDS Associates (12). The ISO-NE reference document provides EULs for the Northeastern part of the U.S. served by ISO-NE. The measure EULs provided in the Protocols and these two secondary sources are presented in Table 3-11.

Table 3-11
Measure Lives Comparison

Measure	2007 New Jersey Protocols	CEC 2008 Database for Energy Efficiency Resources (DEER)	ISO-NE Forward Capactiy Market Reference Document
Central Air Conditioner	15	15	18
Proper sizing/Install	15		
Air Source Heat Pump	15	15	18
Ground Source Heat Pump	30		
Furnace	20	20	18
Boiler	20		18
Water Heater (gas)	10	11	

The 2007 Protocol heating and cooling measure EULs are the same as the EULs in DEER with the exception of water heaters. The ISO-NE EULs are lower for the heating measures and higher for the cooling measures. The difference between the California and New England EULs is consistent with the different levels of usage the measure would experience in the two climates. Heating measures will be used more in New England than California and, thus, will breakdown sooner. The same goes for cooling measures in California.

New Jersey's climate falls somewhere between the two climate extremes. New Jersey is hotter, and more humid, than most of New England but will have fewer cooling hours than the majority of California. The Protocol EUL of 15 years for cooling-related measures is at the low, conservative end of the range presented here.

With regard to heating, New Jersey has greater heating hours than California and fewer than New England. The Protocol EUL of 20 years for heating-related measures is identical to California, so at the high end of the range presented here. An EUL of 18 years would be more conservative for heating measures, reflecting the increase use of the measure in New Jersey relative to the use in California. The actual New Jersey EUL should fall somewhere between these two values. The difference between the two measures lives is not sufficient to justify recommending a change to lower EUL

Only DEER provides an alternative EUL for water heaters. As water heaters usage patterns are not weather dependent, the DEER EUL should be roughly equivalent to the New Jersey EUL. The difference does not justify changing New Jersey water heater measure life.

3.4 General Protocol Recommendations

The authors of the Protocols have researched the algorithms and associated input values and have provided sources. Where we have found the sources, we have examined them. If the source was unclear or unavailable, we have tried to find secondary sources. Key recommendations include:

- Adopt the impact evaluation estimates of Equivalent Full Load Hours (EFLH) for heating and cooling, 727 and 501 hours, respectively.
- Re-evaluate the 2007 Protocol proper sizing and QIV factors. Going forward, these factors will determine the majority of program cooling related savings. The billing analysis supports a maximum energy savings factor (combined proper sizing and quality installation verification) of 9.2 percent of installed usage. Installation-related demand savings cannot be estimated from the billing analysis. However, Demand savings should not be greater than energy savings. In the absence of better evidence, the demand savings factor should also be set at 9.2 percent of installed demand.
- Adjust installation-related factors (proper sizing, QIV or duct sealing) to properly calculate savings from the estimated unit usage. Savings percentages from research are measured with respect to units without quality installation verification. Percentages need to be adjusted to get the proper savings from the usage estimated by the Protocol algorithms which include the effects of these quality installation improvements.
- Further research the coincidence factor of participant units. Proper sizing and QIV can have mixed effects on peak loads at extreme temperatures. The program coincidence factor should accurately reflect the coincidence factor of CoolAdvantage units at peak temperatures.
- Replace typical furnace or boiler output capacity (91,000 Btu) with individual qualifying unit output capacity in the heating savings equation.
- Continue to update the typical replacement heating equipment AFUE values using previous methodology. Include information on market share of unit types, if possible.
- Lower baseline water heater usage in the water heating saving equation from 212 therms to 180 based on regional estimates of average water heating usage.
- The Warm- and CoolAdvantage rebate applications are designed well to collect the necessary data for program tracking and evaluation purposes. The challenge with collecting tracking data is getting the data recorded accurately in the field and then transferring it successfully into a well-designed database that captures all of the necessary program data. The Warm- and CoolAdvantage programs can improve

substantially in this respect. Of particular importance is the capturing of QIV and right-sizing activity that takes place.

- QIV and right-sizing activity by contractors needs to be validated by the program.

Further recommendations include:

- EFLH for heating is defined three times with either different values or notations. The first is heating EFLH defined as 2250 hours. The second is heating EFLH defined as 965 hours. The third is $EFLH_{HT}$ defined as 965 hours. The protocol does not provide any argument supporting three separate definitions which can result in confusion. In addition, we are unable to substantiate any difference in heating EFLH for a given capacity from one system type to another. The multiple definitions should be eliminated or substantiated and clearly defined. Finally, cooling EFLH should be listed as $EFLH_C$ and heating EFLH should be listed as $EFLH_H$ to eliminate any remaining confusion. We have followed this recommendation in the preceding pages for clarity.
- For furnace fans, the units applied to FFS_{HT} are inconsistent with the equation. The units should be kWh/therm rather than kWh. This should also reduce confusion.
- Throughout the existing protocol, many variables have been defined that are no longer used. These include ESF, DSF, Time Period Allocation Factors, the average annual heating use ($\overline{TH}_Q$), the average AFUE ($\overline{AFUE}_Q$) and the average output capacity ($\overline{CAPY}_Q$). To reduce confusion, we recommend revising the protocol document to eliminate this extraneous information.

Table 15 provides a summary of the recommended changes to the 2007 Protocols.

Table 3-12
Recommended Changes Matrix

2007 Protocol		Recommended	
Component	Value or Equation	Component	Value or Equation
$EFLH_C$(Cooling Equivalent Full Load Hours)	600 Hours	$EFLH_C$	501 Hours
PSF (Proper Sizing Factor)	5% of post program usage or demand	ESF (Energy savings factor) DSF (Demand savings factor)	9.2% of post program usage or demand
QIF (Quality Installation Factor)	15% of post program usage or demand		
Cooling Energy Savings for Proper Sizing (Eq. 5)	$kWh_P = kWh_Q * PSF$	Cooling Energy Savings for Proper Sizing and QIV.	$kWh_P = kWh_Q * ESF$
Cooling Energy Savings for Quality Installation Verification (Eq. 7)	$kWh_V = kWh_Q * (1 - PSF) * QIF$		
Cooling Energy Savings for Proper Sizing (Eq. 6)	$kW_P = kW_Q * PSF$	Cooling Demand Savings for Proper Sizing and QIV.	$kW_P = kW_Q * DSF$
Cooling Energy Savings for Quality Installation Verification (Eq. 8)	$kW_V = kW_Q * (1 - PSF) * QIF$		
$EFLH_H$ (Heating Equivalent Full Load Hours)	2250 Hours (Heat pump), 965 Hours (Furnace or boiler)	$EFLH_H$	727 Hours
$CAPY_T$ (Output capacity of typical heating unit, in Btu/hr)	91,000 Btu/hr	$CAPY_T$	$CAPY_Q$
Heating Gas Savings (Eq. 22)	$\Delta TH_S = \left[\left(\frac{CAPY_T}{AFUE_B}\right) - \left(\frac{CAPY_Q}{AFUE_Q}\right)\right] * \left(\frac{1 therm}{100,000\, Btu}\right) * EFLH_H$	Heating Gas Savings with baseline typical capacity equal to new capacity.	$\Delta TH_S = \left[\left(\frac{CAPY_Q}{AFUE_B}\right) - \left(\frac{CAPY_Q}{AFUE_Q}\right)\right] * \left(\frac{1 therm}{100,000\, Btu}\right) * EFLH_H$
BWHU (Annual Baseline Water Heater Usage, in therms)	212 therms	BWHU	180 therms

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4. Impact Evaluation Methodology

This section describes the methodologies employed to perform the impact analysis portion of this evaluation. First we provide a high-level overview to provide context for all the individual pieces. Then we go into greater detail for each of the pieces of the analysis.

4.1 Analysis Overview

This evaluation has the dual purpose of providing ex-post impact estimates while also providing empirical grounds for recommended changes to the Protocol savings algorithms. The billing analysis approach we adopt here serves both ends.

For ex-post impact estimates, we rely on billing analysis to provide empirical information about usage rates. The ex-post analysis uses the engineering equations that are the basis of the Protocols to derive impact estimates based on these usage rates. The ex-post analysis also provides an empirical basis for recommended modifications to the Protocol formulas.

Two broad approaches to the billing analysis for ex-post impacts were considered: post-only and pre-post. The post-only approach estimates the post-program usage level, and requires engineering formulas to determine savings relative to baseline equipment for the same usage level. Changes in usage level (take-back) can be accounted for only via engineering analysis of survey responses.

The pre-post approach models total change and, in principle, also captures take-back effects. To get to savings related to the efficiency measures, it is necessary to control for changes in total area heated or cooled, as well as other changes in the home around the same time. Furthermore, this approach models change relative to the old, replaced heating and cooling system rather than relative to standard-efficiency new equipment. Information on the replaced system is necessary to calculate the savings relative to the standard baseline set by the program. Given the lack of information on the replaced system, we employ the pre-post approach primarily to help confirm the magnitude of the results generated by the post-only approach.

The estimation of water heating savings has additional challenges beyond those of heating and cooling savings. Water heating usage is primarily part of a household's baseload usage, and is not separately estimated via the billing analysis. Thus, pre-post analysis is necessary to determine savings associated with water heater replacement. Furthermore, the efficiency-related savings are relatively small. Because of the combination of these factors, the ex-post impact analysis was unable to derive savings estimates for water heater measures.

4.1.1 Discussion of Potential AC Savings

An important part of this impact evaluation is assessing the validity of installation-related savings for the CoolAdvantage Program. As standard baselines increase, installation-related savings become an increasingly large part of the potential savings generated by an AC program. This additional importance to installation-related savings requires a more nuanced understanding of AC usage and how basic engineering equations characterize that usage.

The standard approach to determining change in usage across existing, standard and qualifying units depends solely on SEER. Assuming capacity and EFLH are effectively constant across the three scenarios, the different levels of usage across the three units is determined by nameplate SEER. Figure 1 provides a simple representation of usage levels for existing, standard and efficient units. $\Delta E_{old\text{-}std}$ is the difference in usage between the existing unit that was replaced (unknown SEER but estimated at 9.5 for this example) and standard efficiency unit (SEER 11)[13]. $\Delta E_{std\text{-}qual}$ is the difference in usage between the standard efficiency unit and the unit that qualifies for the CoolAdvantage Program. $\Delta E_{old\text{-}std}$ and $\Delta E_{std\text{-}qual}$ are both easily calculated using the engineering calculations for change in efficiency (equation 1 for cooling and equation 22 for heating).

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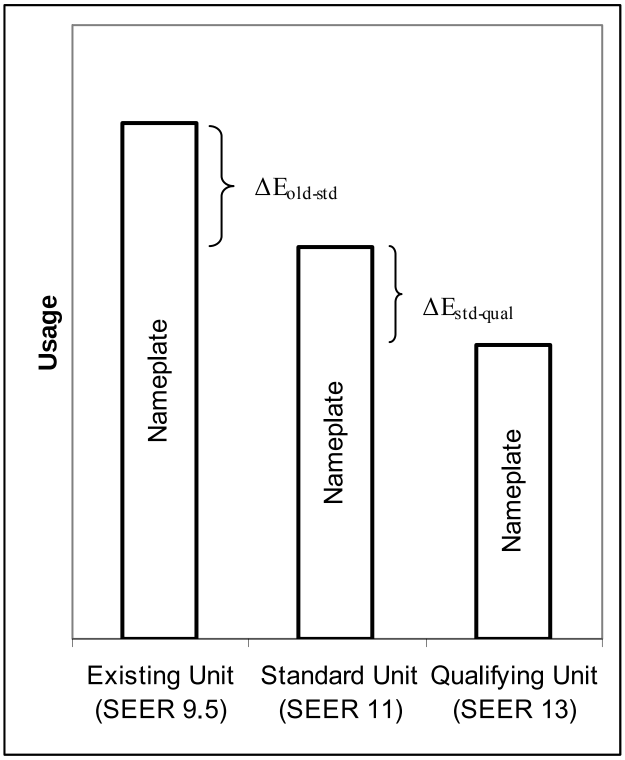
[13] For the purpose of this illustration we will use the baseline SEER used in the 2004 Protocols, the SEER applicable to the units under evaluation.

Figure 1
Illustrative Comparison of Nameplate SEER Usage across Existing, Standard and Qualifying Units



The pre-post billing analysis approach provides an estimate of the difference between the usage of the unit that was in place and the usage of the new qualifying unit ($\Delta E_{old-std}$ + $\Delta E_{std-qual}$). The ultimate goal, however, is to identify the difference between the usage of the standard efficiency unit that would have been installed without the program and the usage of the new qualifying unit ($\Delta E_{std-qual}$).[14] The change in efficiency engineering equations are used to remove $\Delta E_{old-std}$ from the overall change, thus isolating $\Delta E_{std-qual}$, the relevant change in usage for the evaluation.

As long as AC programs were primarily focused on efficiency-related savings, this simplified nameplate SEER approach was satisfactory. An implicit assumption in this approach, however, was that the units in all three scenarios were, in fact, operating at nameplate SEER. Taking into consideration installation savings complicates the assumption of nameplate SEER. Figure 2

[14] The possibility that a participant would have installed an energy efficient unit in the absence of the program is accounted for by the free ridership estimate.

provides a more accurate representation that captures different levels of usage based on different levels of effective SEER.

Figure 2
Illustrative Comparison of Effective and Nameplate SEER Usage Across Existing, Standard and Qualifying Units

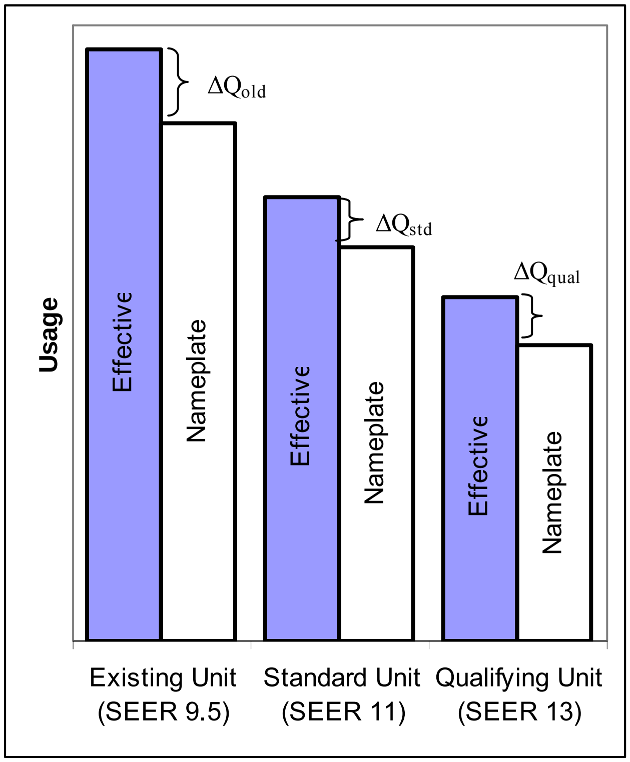


Figure 2 shows that each scenario has a higher level of usage for effective SEER compared with nameplate SEER. Effective SEER represents the actual efficiency level at which the unit operates. For the standard units (ΔQ_{std}) and qualifying units (ΔQ_{qual}), both of which are newly installed units, the difference between effective and nameplate usage is, at least in part, the combined effects of all the issues that can be corrected with a quality installation. For the existing unit (ΔQ_{old}), the difference between effective and nameplate SEER includes the ongoing effects of poor installation as well as any degradation accumulated over the life of the unit.

Considering Figure 2, the pre-post billing analysis estimates the change from the highest level of usage to the lowest level of usage. That is, the analysis estimates the change from existing unit usage at effective SEER to qualifying unit usage at nameplate SEER ($\Delta E_{old\text{-}std} + \Delta E_{std\text{-}qual} + \Delta Q_{old}$). The pre-program usage reflects the existing unit at the level at which it operates. The post-program usage reflects the qualifying unit with quality installation verification. If the QIV measure works, the qualifying unit ought to be closer to nameplate SEER usage than without QIV.

Using the two figures, when $\Delta E_{old\text{-}std}$ is removed from the pre-post billing analysis estimate, the remaining change in usage equals $\Delta E_{std\text{-}qual} + \Delta Q_{old}$. Though it is particularly difficult to account for the working status of the existing unit, it is only reasonable to assume that ΔQ_{old} is greater than ΔQ_{qual}. ΔQ_{old} includes all the inefficiencies of the original installation when the unit was first installed along with any additional inefficiency caused by the unit's aging. At a minimum, ΔQ_{old} provides an absolute upper bound on ΔQ_{qual}.

The pre-post billing analysis result does not break out $\Delta E_{std\text{-}qual} + \Delta Q_{old}$ into its two constituent parts. Fortunately, the post-program billing model provides a separate estimate of $\Delta E_{std\text{-}qual}$ based on the post-program, qualifying unit usage directly from participant billing records[15]. Thus, the pre-post billing analysis estimate of ΔQ_{old} is readily netted out. This provides an estimate of ΔQ_{old} which in turn provides the upper bound with which to compare the estimate of ΔQ_{qual} produced using the Protocol equations.

The illustrations developed here will be referred to throughout the rest of this section. While this section is specifically design to explore issues unique to the cooling savings algorithms, the basic concepts also apply to the gas heating billing models as well.

4.2 Billing Analysis

This impact evaluation uses a pooled time series, cross-section approach to billing analysis. The approach models multiple premises over multiple time periods controlling for premise and time period-specific effects. The model generates estimates of heating and cooling energy usage. In the pre-post specification, the model generates further estimates of the change in usage between the pre- and post-program periods.

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[15] Even with the QIV process, units are unlikely to operate exactly to specifications, or nameplate SEER. The purpose of this illustration, it simply matters that the QIV process lowers the usage some increment. Further splitting out these changes in usage is unnecessary for the example to clarify the issues.

4.2.1 General Billing Analysis Approaches

4.2.1.1 Post-Program Usage Billing Regression

The post-program usage billing regression includes data for each participant only from time periods after that customer's program participation. The basic equation is:

$$E_{im} = \mu_i + \lambda_m + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \varepsilon_{im} \quad \text{Equation 28}$$

where

E_{im}	=	Energy used per day during month *m* for customer *i*;
$H_{im}(\tau_H)$	=	Heating degree-days at the heating base temperature τ_H during month m, based on daily average temperatures, for customer i's meter reading period;
$C_{im}(\tau_C)$	=	Cooling degree-days at the cooling base temperature τ_C during month m, based on daily average temperatures, for customer i's meter reading period;
μ_i	=	Premise-specific baseload estimate for customer i;
λ_m	=	Month-specific time period effect for month m;
β_H, β_C	=	Heating and Cooling coefficients determined by the regression;
τ_H τ_c	=	Heating and Cooling degree-day base temperatures determined by choice of the optimal regression; and
ε_{im}	=	Regression residual.

In this equation, energy is a function of a premise-specific constant (baseload μ_i) and heating and cooling degree days $H_{mi}(\tau_H)$, $C_{mi}(\tau_C)$ (heating and cooling usage drivers). Monthly bill reads divided by the number of days in the billing period provide the daily energy amounts E_{im}. Average daily degree days for the billing period are calculated from daily average temperature for the days in the bill period. The heating and cooling degree-days for a given month vary over customers i because the read dates within the month vary.

The month-specific time period terms are an important feature of this fixed effects model. The time period coefficients λ_m account for systematic effects correlated with the time period but not explained by the other variables. These terms will account for a wide range of systematic effects including economic factors, natural disasters, unusual weather not accounted for by the simple degree-day terms, etc.

The basic model presented above can include additional variables that are appropriate to interact with the heating or cooling degree day terms. For the majority of both heating and cooling measures, the size of the installed unit was recorded in the tracking data. Using these data we can account for usage varying with respect to unit capacity as well as degree days. For both heating and cooling billing regressions, in addition to degree days, we also included an interacted degree days/capacity variable in initial runs of the model.

We test the full model across a range of degree day bases. Across model runs with the same variable combinations, the R^2 provides a simple way to find the optimal (maximum likelihood) combination of heating and cooling degree day bases. This effectively estimates the average outdoor temperature at which heating or cooling begins among the included households. If the optimal model includes heating or cooling variables that are not statistically significant, they are removed one at a time and the degree day bases re-optimized.

4.2.1.2 Pre-Post Usage Billing Regression

The billing analysis approach discussed above uses only post-program usage. The same general billing analysis regression is also applied to both pre- and post-program billing records with variables included to capture the pre-post change in usage. The equation for the pre-post approach is a variant of the pooled, time-series cross-section model discussed above. The simplest version of the pre-post model is

$$E_{im} = \mu_i + \lambda_m + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \delta P_{im} + \varepsilon_{im} \qquad \text{Equation 29}$$

where

P_{im}	=	an indicator variable equal to zero for months m prior to program participation by customer i, and one after program participation
δ	=	Estimate coefficient on the participation indicator variable, change in usage in the units of the usage variable

In the pre-post billing regression the heating and cooling usage parameters represent pre-program usage. The coefficient on the participation variable represents average change in usage between the pre- and post- installation periods. The participation effect can be interacted with degree days and/or capacity to capture changes in usage that are correlated with temperature and/or unit size.

The time period effects are of particular importance in the pre-post billing regression. In the pre-post model, only a small proportion of households are in change mode in any give month. All other households are in a steady state pre- or post-program usage mode. These households not in change mode contribute to a consistent measurement of time period effects across all time periods despite the fact that all households go through a structural change at some point in the period.

The pre-post billing analysis approach relies on the time-period effects to pick up any general trends in usage. Other household-specific usage changes add to the variation in the estimate but will not generally affect the estimated coefficients. Actions that potentially change a household's usage occur throughout the time span of the analysis and can increase or decrease usage. To affect the coefficient estimates, changes would have to be correlated with the post-program period but not be related to the program, as well as having a meaningful positive or negative effect on average.

4.2.2 Electric Billing Regressions

The final specification for the post-program electric billing regression includes heating degree days and cooling degree days interacted with CAC capacity. With the capacity-interacted variable included in the model, cooling degree days as a non-interacted variable was not statistically significant. The equation is

$$E_{im} = \mu_i + \lambda_m + \beta_H H_{im}(\tau_H) + + \beta_C C_{im}(\tau_C) * CAP_i + \varepsilon_{im}$$ **Equation 30**

where

CAP_i	=	Capacity in Btu for unit *i*
β_H, β_c	=	Estimated coefficients on the heating degree days and cooling degree days/Capacity combination variables

The final specification for the pre-post billing regression is

$$E_{im} = \mu_i + \lambda_m + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \delta_1 P_{im} C_{im}(\tau_C) + \delta_2 P_{im} CAP_i + \delta_3 P_{im} C_{im}(\tau_C) CAP_i + \varepsilon_{im}$$

Equation 31

where

$\delta_1, \delta_2, \delta_3$ = Estimated coefficient on the participation indicator variable interacted with cooling degree days, capacity and both variables combined

4.2.3 Electric Impact Estimates

The post-only billing regression provides the basis for an estimate of the impact of efficiency-related savings due to the program. The pre-post billing regression provides a parallel result that supports the post-only estimate.

4.2.3.1 Post-Program Billing Analysis Impact Estimate

The post-program billing analysis result provides an empirically-based estimate of post-program usage. This estimate of usage is associated with a level of EFLH using engineering equations. This provides an alternative estimate of EFLH for comparison to the 600 hours used in the Protocols. Using the Protocol equations with this alternative estimate of EFLH, produces an impact estimate based on participant post-program cooling usage.

4.2.3.1.1 Empirically-Based EFLH

The Protocol equation for cooling usage (Equation 3) is rearranged to solve for EFLH,

$$EFLH_C^* = \frac{1}{CAPY_Q Btu} * \left(1000 \frac{Wh}{kWh}\right) * SEER_Q \frac{Btu}{Wh} * \hat{k}Wh_Q .$$

Equation 32

where

$\hat{k}Wh_Q$ = Post-only estimate of cooling usage in a normal weather year

$CAPY_Q$ = Median qualifying unit capacity

$SEER_Q$ = Median qualifying unit SEER

$EFLH_C^*$ = Updated estimate of EFLH using post-only billing analysis usage

This equation defines a fixed relationship between usage and EFLH given the SEER and capacity of the installed units. Given the estimate of post-program cooling usage from the billing regression, this equation provides the associated EFLH.

While this is a standard use of this engineering equation, it is important to understand its assumptions in the context of a program including a QIV component. Strictly speaking, the SEER used in the equation assumes nameplate SEER installed to manufacturers' specifications. This is a detail that is rarely specified when this equation is used. Instead, the nameplate SEER value is used in the equation regardless of the effective level of SEER the unit is operating under. As a result, the EFLH derived from this equation is contingent on the effective SEER underlying the cooling usage.

Our review of the QIV process indicates that it is unrealistic to expect all installed units to operate at nameplate SEER. Using this equation, the estimate of EFLH will move lower as the actual SEER of the installed units converges on nameplate SEER. The CoolAdvantage Program QIV process makes it more likely that the installed units are performing at a level close to the nameplate SEER. This implies that estimates of EFLH based on participant usage will be lower than previous EFLH estimates that were based on usage levels without the effect of QIV.

This may explain the lower estimate of EFLH derived for this impact evaluation. Accordingly, the lower EFLH is appropriate because it reflects the effective SEER underlying participant cooling usage. Importantly, savings lost as a result of the lower EFLH value should be reflected in the QIV savings.

4.2.3.1.2 Efficiency-Related Impact Estimate

The ex-post impact analysis uses the same savings equations as the Protocols. The billing analysis-based estimate of EFLH replaces the Protocol estimate of EFLH to produce the ex-post impact estimates. For cooling, the standard protocol equation with the new estimate of EFLH is

$$\Delta kWh_S = CAPY_Q * \left(\frac{1}{1000}\right) * \left(\frac{1}{SEER_S} - \frac{1}{SEER_Q}\right) * EFLH_C^* \qquad \text{Equation 33}$$

where all inputs are as defined above.

ΔkWh_S represents efficiency-related savings generated by the program. That is, all else being equal (in this case, $CAPY_Q$ and $EFLH_C$*), the change in efficiency from standard baseline to the average program SEER reduces usage by this amount.

For the ex-post impact evaluation, $SEER_S$ is the standard baseline SEER of 11 as existed during 2005 and 2006. As one of the purposes of this evaluation is to understand the potential for savings in future years, we also develop results using the new standard baseline SEER of 13. This higher baseline substantially reduces the efficiency-related savings that will be awarded the program with the 2007 Protocols.

4.2.3.2 Pre-post Electric Billing Analysis Impact Estimate

The pre-post billing analysis result provides a measure of the raw pre-post program change in usage. Importantly, this result reflects characteristics of the program population, including:

- The percentage of households that are installing a central AC for the first time. This is in contrast to households replacing an existing CAC.
- Partial changes in usage, i.e. CACs replacing multiple room ACs or cooling additional floorspace from an addition.
- For those households replacing an existing unit, the efficiency (SEER) of the old unit being replaced.

Each of these characteristics affects the raw pre-post usage difference differently. If a CAC is installed where no AC of any sort previous existed, the usage difference will be an increase equal to the usage of the new unit. If an older CAC unit is replaced with a similarly sized unit, the efficiency level of the replaced unit is the ultimate determinant of change in usage. Finally, partial increases in capacity will have an effect somewhere between these two effects.

These issues can be addressed with a series of adjustments using a combination of survey results and data from secondary sources. We use survey results to provide estimates for the first two of the three factors. Secondary sources provide reasonable estimates of replaced unit efficiency as well as previous room AC usage. With these data, the pre-post billing analysis produces estimates of the change in usage.

4.2.3.2.1 Adjustment for Added AC Units

The raw pre-post billing analysis result gives the average per-unit change in cooling usage from before to after the program. The result combines the usage difference for replaced CACs (likely decreased cooling usage) and CACs installed for the first time (increased usage). For the latter, it's assumed a new CAC of the same capacity but standard efficiency would have been installed without the program. They are, in fact, only included in the billing analysis because the tracking data did not contain consistent data on replacement versus first-time installs. The first adjustment removes the effect of first-time installers. Controlling for new CAC installations isolates the change in usage from the existing unit to the qualifying program installation. This adjustment is necessary to get to the starting point of the discussion in section 4.1.1.

The following equation describes the makeup of the pre-post regression result as a weighted average between the decreased usage for a replaced unit and the increased usage from a new CAC unit. For households with first-time CAC installations, the change in usage will be the usage of the new CAC net of prior room AC usage. This is accounted for in the equation.

$$\Delta kWh_R = a*(kWh_Q - RAC) + (1-a)\Delta kWh_X \quad \text{Equation 34}$$

ΔkWh_R	=	Pre-post change in usage from Billing regressions,
kWh_Q	=	Qualifying unit annual Usage,
RAC	=	Average room AC usage across for first-time CAC installers,
ΔkWh_X	=	Annual kWh savings from Existing efficiency to new efficiency,
a	=	Percentage of household installing CACs for first time.

The qualifying unit annual kWh can be described as the combination of existing unit annual kWh and the negative change in usage from existing unit to new unit.

$$kWh_Q = kWh_X + \Delta kWh_X \quad \text{Equation 35}$$

Combined, the two equations become

$$\Delta kWh_R = a*(kWh_X + \Delta kWh_X - RAC) + (1-a)\Delta kWh_X \,. \quad \text{Equation 36}$$

Simplified, the equation becomes

$$\Delta kWh_R = a*(kWh_X - RAC) \qquad + \Delta kWh_X \,. \quad \text{Equation 37}$$

Solved for the change in usage from existing efficiency, the equation is

$$\Delta kWh_X = \Delta kWh_R - a*(kWh_X - RAC) \quad . \quad \text{Equation 38}$$

Combined, the equations simplify to a calculation of change in usage from existing to qualifying unit as a function of the original regression pre-post difference, the regression estimate of pre-program cooling usage, an external estimate of room AC usage, and the percentage of first-time AC installs. The room AC usage RAC is based on an engineering estimate together with the reported room AC incidence from the survey. The percentage of first-time installs is determined from the survey.

4.2.3.2.2 Adjustment for Standard Efficiency Base

The adjustment discussed in the previous section isolates the change in usage associated with the replacement of an existing CAC with a qualifying unit. The program only gets credit for efficiency related savings relative to standard efficiency because the program assumes that, in the absence of the program, all CAC installations would have taken place at standard efficiency. Thus, the next step isolates change in usage from the standard unit baseline to qualifying program installation. Referring back to Figure 1 in section 4.1.1, this involves removing $\Delta E_{old\text{-}std}$.

The basic efficiency related cooling savings equation from the Protocols expresses savings given an increase in SEER from standard unit to qualifying unit efficiency.

$$\Delta kWh_S = CAPY_Q * \left(\frac{1}{1000}\right) * \left(\frac{1}{SEER_S} - \frac{1}{SEER_Q}\right) * EFLH \quad \text{Equation 39}$$

The same equation can also expresses savings given an increase in SEER from existing unit to qualifying unit efficiency.

$$\Delta kWh_X = CAPY_Q * \left(\frac{1}{1000}\right) * \left(\frac{1}{SEER_X} - \frac{1}{SEER_Q}\right) * EFLH \quad \text{Equation 40}$$

These two equations are combined to create an equation that defines impact relative to standard efficiency as a scaled version of impact relative to existing efficiency.

$$\Delta kWh_S = \Delta kWh_X * \left(\frac{1}{SEER_S} - \frac{1}{SEER_Q}\right) \Big/ \left(\frac{1}{SEER_X} - \frac{1}{SEER_Q}\right) \quad \text{Equation 41}$$

The SEER of the existing unit is unknown and could fall anywhere between a low of 8 and a high of 10. Rather than assume a single value for existing unit SEER, we provide impact estimates for the full range of possible existing unit SEERs.

4.2.4 Furnace Billing Regressions

The final specification for the post-program furnace billing regression includes heating degree days and heating degree days interacted with furnace capacity. The final specification of the gas heating billing regression is

$$E_{im} = \mu_i + \lambda_m + \beta_{H2} H_{im}(\tau_H) + \beta_{H1} H_{im}(\tau_H) * CAP_i + \varepsilon_{im}$$

where

CAP_i	=	Capacity in Btu for unit *i*
β_{H1}, β_{H2}	=	Estimated coefficients on the heating degree days and heating degree days/Capacity combination variables

$$E_{im} = \mu_i + \lambda_m + \beta_H H_{im}(\tau_H) + \delta_1 P_{im} H_{im}(\tau_H) + \delta_2 P_{im} CAP_i + \delta_3 P_{im} H_{im}(\tau_H) CAP_i + \varepsilon_{im} \quad \text{Equation 42}$$

where

δ_1, δ_2, δ_3	=	Estimated coefficient on the participation indicator variable interacted with heating degree days, capacity and both variables combined.

4.2.5 Gas Impact Estimates

The post-only billing regression provides the basis for an estimate of the impact of efficiency-related savings due to the program. The pre-post billing regression provides parallel results that support the post-only estimate.

4.2.5.1 Post-Program Billing Analysis Impact Estimate

The post-program billing analysis result provides an empirically-based estimate of post-program usage. This estimate of usage is associated with a level of EFLH using engineering equations. This provides an alternative estimate of EFLH for comparison to the 965 hours used in the 2007 Protocols. Using the Protocol equations with this alternative estimate of EFLH, produces an impact estimate based on participant post-program heating usage.

4.2.5.1.1 Empirically-Based EFLH

The Residential Gas Protocol includes the equation for EFLH as a function of heating usage (Equation 23). For the impact evaluation, the equation becomes

$$EFLH^*_H = \hat{T}H_Q * \left(100{,}000 \frac{1therm}{Btu}\right) * \left(\frac{\overline{AFUE}_Q}{\overline{\overline{CAPY}}_Q}\right). \quad \text{Equation 43}$$

where

$\hat{T}H_Q$	=	Post-only estimate of heating usage in a normal weather year
$EFLH_H^*$	=	Updated estimate of EFLH using post-only billing analysis usage
$\overline{AFUE}_Q$	=	Median heating unit efficiency
$\overline{CAPY}_Q$	=	Median heating unit capacity (Btu)

4.2.5.1.2 Efficiency-Related Impact estimate

The ex-post impact analysis uses the same savings equations as the Protocols. The billing analysis-based estimate of EFLH replaces the Protocol estimate of EFLH to produce the ex-post impact estimates. For heating savings, the protocol equation with the new estimate of EFLH is

$$\Delta TH_S = \left[\left(\frac{CAPY_T}{AFUE_B}\right) - \left(\frac{CAPY_Q}{AFUE_Q}\right)\right] * \left(\frac{1therm}{100{,}000Btu}\right) * EFLH_H^* \qquad \text{Equation 44}$$

Where all inputs are as defined above.

ΔTH_S represents efficiency-related savings generated by the program. Unlike the cooling savings protocol, there are no associated savings related to proper installation. Also unlike the cooling savings Protocol, the standard baseline efficiency (AFUE) is not changing between 2004 and 2007, or in the immediate future. In this respect, the ex-post impact evaluation results also provide the efficiency-related savings that will be awarded with the 2007 Protocols.

One change was recommended in the Protocol review and it would affect the savings awarded were it adopted. The present equation uses a “typical” capacity for the baseline portion of the equation. As discussed in the Protocol review, the equation would better reflect actual program savings if it instead used the qualifying unit capacity for both capacities present in the equation. The equation is otherwise identical.

$$\Delta TH_S = \left[\left(\frac{CAPY_Q}{AFUE_B}\right) - \left(\frac{CAPY_Q}{AFUE_Q}\right)\right] * \left(\frac{1therm}{100{,}000Btu}\right) * EFLH_H^*$$ **Equation 45**

We present results for heating savings calculated with this recommended equation. If this recommendation were accepted, these results would reflect the revised Protocol heating savings for the program.

4.2.5.2 Pre-post Furnace Billing Analysis Impact Estimate

The heating pre-post billing analysis result provides a measure of the gross pre-post program change in usage. Importantly, this result reflects characteristics of the program population, including:

- The percentage of households that are installing gas heat in place of some other fuel. This is in contrast to households replacing an existing gas furnace.
- For those households replacing an existing unit, the efficiency (AFUE) of the unit being replaced.
- Partial changes in usage, e.g. heating additional floorspace from an addition.

Each of these characteristics affects the gross pre-post usage difference differently. If a gas furnace or boiler replaces a heating unit using some other fuel, the usage difference will be an increase equal to the usage of the new unit. If an older gas unit is replaced with a similarly sized unit, the efficiency level of the replaced unit is the ultimate determinant of change in usage. Finally, partial increases in capacity will have an effect somewhere between these two effects.

4.2.5.2.1 Adjustment for Fuel Switching

The heating pre-post billing analysis result gives the average per-unit change in heating usage caused by the program-related furnace or boiler installation. The result combines the usage difference for replaced gas units (likely decreased usage) and gas units replacing heating by some other fuel (increased usage). Controlling for the increase in usage due to fuel-switching participants isolates the relevant change in usage between existing unit and the qualifying program installation.

The following equation describes the makeup of the pre-post regression result as a weighted average between the decreased usage for a replaced gas unit and the increased usage from a fuel-switching unit.

$$\Delta TH_R = a * (TH_Q) + (1 - a)\Delta TH_X$$ Equation 46

where

ΔTH_R	=	Pre-post change in usage from Billing regressions
TH_Q	=	Annual Therm post-program Usage
ΔTH_X	=	Annual Therm savings from Existing efficiency to new efficiency
a	=	Percentage of household switching fuels[16]

The qualifying unit annual therms can be described as the combination of existing unit annual therms and the negative change in usage from existing unit to new unit.

$$TH_Q = TH_X + \Delta TH_X \quad \text{Equation 47}$$

Combined, the two equations become

$$\Delta TH_R = a * (TH_X + \Delta TH_X) + (1 - a)\Delta TH_X\,. \quad \text{Equation 48}$$

Simplified, the equation becomes

$$\Delta TH_R = a * TH_X \quad + \Delta kWh_X\,. \quad \text{Equation 49}$$

Solved for the change in usage from existing efficiency, the equation is

$$\Delta TH_X = \Delta TH_R - a * TH_X \quad . \quad \text{Equation 50}$$

The equations simplify to calculate the change in usage from existing to qualifying unit as a function of the original regression pre-post difference, the regression estimate of pre-program heating usage and the percentage of installations replacing non-gas units.

4.2.5.2.2 Adjustment for Standard Efficiency Base

The adjustment discussed in the previous section isolates the change in usage associated with replacing an existing unit. The program only gets credit for part of this change – that is, the efficiency related savings from standard efficiency to qualifying unit. Thus, change in usage from the existing unit must be further adjusted to isolate change in usage from the standard unit baseline to qualifying program installation.

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[16] The heating tracking data included information on fuel-switching. The percentage used for this input, 16.4 percent, came directly from the tracking data rather than the survey.

The basic efficiency related heating savings equation from the Protocols expresses savings given an increase in AFUE from standard unit to qualifying unit efficiency.

For heating the equations is

$$\Delta TH_S = \left[\left(\frac{CAPY_Q}{AFUE_B} \right) - \left(\frac{CAPY_Q}{AFUE_Q} \right) \right] * \left(\frac{1 therm}{100{,}000 Btu} \right) * EFLH \qquad \text{Equation 51}$$

where all inputs are defined as above. The equation can also be formulated to calculate the change from existing to qualifying efficiency.

$$\Delta TH_X = \left[\left(\frac{CAPY_Q}{AFUE_X} \right) - \left(\frac{CAPY_Q}{AFUE_Q} \right) \right] * \left(\frac{1 therm}{100{,}000 Btu} \right) * EFLH \qquad \text{Equation 52}$$

The two equations are then combined to provide an adjustment that isolates the change in usage from standard to qualifying unit efficiency.

$$\Delta TH_S = \Delta TH_X \left(\frac{1}{AFUE_S} - \frac{1}{AFUE_Q} \right) \Big/ \left(\frac{1}{AFUE_X} - \frac{1}{AFUE_Q} \right) \qquad \text{Equation 53}$$

4.2.5.3 Post-Only vs. Pre-Post Impact Estimates

The post-only and pre-post impact estimates illustrate two different ways of getting at approximately the same result - the savings generated by the program. Both approaches fundamentally rely on engineering equations to extract the impact estimates from the results of the two different kinds of billing analysis.

The post-only approach has its strengths and weaknesses. Its strength is its simplicity. The approach provides estimates of post-program usage and then calculates savings relative to that benchmark. It is easier to obtain post-program billing records, because they are more recent, so a robust estimate of post-program usage is possible. The efficiency savings equation is widely used. The savings percentages for proper sizing and QIV must be set at appropriate levels and be applied correctly. The process for calculating the savings is essentially the same as the one used by the Protocols but is rooted in observed usage levels.

A weakness of the post-only approach is the complete reliance on post-program data. A common concern with energy efficiency programs, in general, is take-back. In theory, because of the lower effective price of heating or cooling, the participant actually increases their heating or cooling usage by changing the thermostat set-point. Post-program usage will be greater than if no take back had occurred. The equations used to calculate savings from post-program usage don't take take back into consideration. In fact, the greater post-program usage will generate a higher estimate of savings. In actuality, take back lowers the pre-post program difference in usage so should decrease the savings estimate.

The pre-post approach also has its strengths and weaknesses. Its strength is that it includes information on pre-program usage levels. This pre-program data holds the promise of providing insight into actual changes in usage. As a result, in theory, this approach accounts for take-back.

The weakness of the pre-post approach comes in the process of deriving the final impact estimate from the raw pre-post billing analysis result. The pre-post billing analysis adjustment process is even more reliant on engineering equations than the post-only approach. In addition, the pre-post approach relies on a variety of assumptions and survey-based estimations. The pre-post approach also relies on there being sufficient pre-program data to fully define pre-program usage levels[17].

Finally, as discussed in section 4.1.1, primarily in regards to cooling, even after all the adjustments, the pre-post billing analysis results may include more than just program-related savings. This is because using engineering equations to replace the existing unit baseline with a standard unit baseline does not address the relative degradation of the existing unit.

For this evaluation we consider the post-only impact estimates more reliable. However, the pre-post impact estimates and other results provide an important perspective on the post-only estimates. Ultimately, the pre-post cooling results appear to confirm our recommendations regarding the magnitude of QIV/sizing savings but give no evidence of take-back. The pre-post heating results, on the other hand, do appear to support the hypothesis of some level of participant take-back.

4.3 Free Ridership

Free ridership measures the fraction of participants' savings that would have occurred without the program. If an energy efficient installation would not have taken place without the program, then there is no free ridership for that unit; the program receives full credit for the savings generated by the installed measure. If the energy efficient installation would have been identical

[17] Accessible archived billing records frequently only go back 24 months.

without the program, then the participant is considered a free rider. The program receives no credit for the savings for that installation.

There are three levels at which free ridership is assessed:

- Awareness of energy efficient alternatives: Without this awareness, it is assumed the program is responsible for motivating the choice of the energy efficient alternative.
- Likelihood of installation without the rebate: For participants aware of the energy efficient alternative, we assess the likelihood that they would have installed that energy efficient alternative without the rebate. This provides the initial level of free ridership.
- Acceleration of installation due to the rebate: Even if a participant had some level of intent to install the energy efficient alternative, the program rebate might motivate the installation to happen sooner than it otherwise would have. If there is evidence of acceleration, the free ridership level is reduced and program credit is increased.

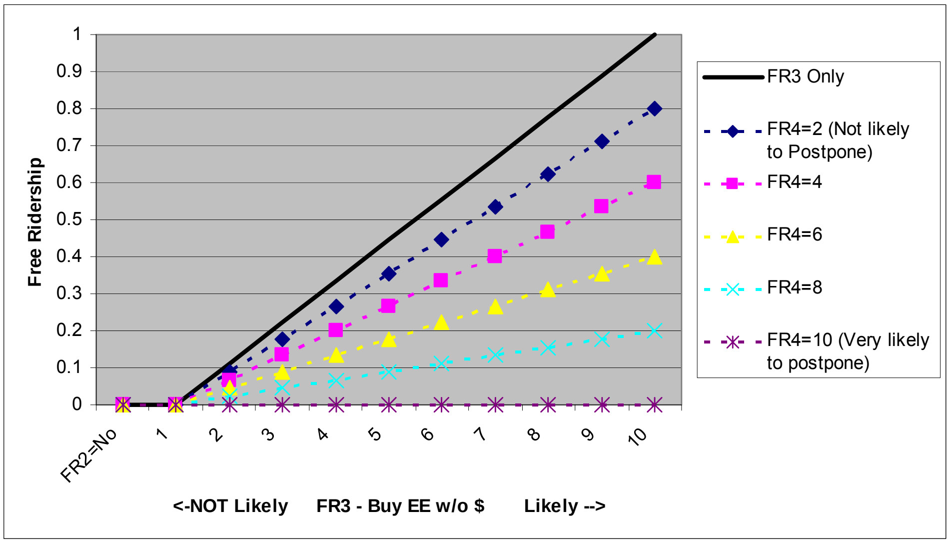
KEMA addresses the issue of free ridership through a short series of questions in the program participant survey. The use of participant self-reports to estimate free ridership is a well accepted energy efficiency program evaluation methodology. Table 4-1 provides the survey questions and the scoring process for those questions.

Table 4-1
Free Ridership Sequence for Warm- and CoolAdvantage Measures

Survey #	Research Question	Question Response	Scoring for Free Ridership
FR2	Prior to approaching your contractor to purchase the new [MEASURE], were you aware that some models were significantly more energy efficient than others?	YES NO	Free Ridership possible. Proceed with sequence. No Free Ridership possible. End Sequence. FR_final=0.
FR3	You received a [REBATEAMOUNT] rebate on the purchase of your energy-efficient [MEASURE]. On a 10-point scale where 1 means "not at all likely" and 10 means "very likely", how likely is it that you would have purchased a [MEASURE] with the same high efficiency rating if you had not been offered the rebate?	1 (not at all likely to buy EE without rebate) to 10 (very likely to buy EE without rebate)	FR_1 = (rating-1) / 9 . If FR_1=0 then End Sequence. FR_final=0.
FR4	**If FR_1 > 0 AND if the purchase was to replace an operative system:** Using the same 10-point scale where 1 means "not at all likely" and 10 means "very likely", how likely is it that you would have postponed the purchase of the energy-efficient system for more than a year?	1 (not at all likely to postpone EE more than a year) to 10 (very likely to postpone EE more than a year)	FR_2 = (10 - rating) / 10.
	Free ridership score (FR_Final)		FR_final = FR_1 * FR_2

Figure 3 provides a visual representation of the free ridership calculation. The X axis gives the range of answers to the initial measure of free ridership (question FR3 in the sequence). The levels of free ridership for that question alone are indicated by the heavy solid line. Question FR4, regarding postponement (acceleration), has the effect of scaling down the initial measure of free ridership. This approach rewards acceleration but does so in the context of single annual estimate of free ridership. The different levels of free ridership associated with responses to FR4 are indicated by dashed lines spanning the range between the initial free ridership levels and zero. Regardless of the initial answer regarding likelihood of purchasing the energy efficient measure, if the participant was very likely to postpone that purchase without the rebate then free ridership is zero and the program receives full credit for that measure's savings. If life cycle savings are calculated, accelerated installations receive two different levels of savings. For the acceleration period, savings are measured relative to the existing unit baseline. After that period, savings revert to standard baseline savings net of free ridership (without acceleration included).

Figure 3
Free Ridership Calculation Ranges



From the scoring of these questions, each survey participant receives a free ridership score ranging from zero (no free ridership, program receives full credit) to one (full free rider, the program receives no credit). Using this score, a mean free ridership estimate was calculated for each measure type.

Participants who were very likely to install without the rebate (FR3=10) were initially full free riders before acceleration was taken into consideration. Any likelihood that the rebate accelerated their installation would have lowered the level of free ridership. Because of an error in the survey skip pattern, these participants were not asked the subsequent question measuring acceleration. All other respondents to FR3 were asked FR4 and we used their answers to FR4 to estimate a level of FR4 for those who were not asked the question.

Across the remaining range of responses to question FR3 (1-9), participants did indicate some likelihood of postponement without the rebate. There was no evidence of a correlation between the levels of response to the two questions so we used the measure-specific mean response to impute the likelihood of postponement for those participants most likely to install without the rebate.

4.4 Spillover

Spillover is defined as the energy savings from additional sales of energy efficient measures motivated in some way by the program but not rebated. A rebate program like WarmAdvantage or CoolAdvantage can motivate spillover in a number of ways. The program may increase stocking of energy efficient measures making them more available to the market overall. Rebates might get a person's attention and motivate the sale but paperwork is never submitted. Finally, in general, these programs help to increase awareness and confidence in energy efficiency products and expand the energy efficiency products market.

Measuring spillover is always a challenging proposition. It's made easier for rebate programs because of the focused scope of the program that is, providing rebates. Participant spillover refers to other non-rebated energy efficiency purchases made by program participants. Non-participant spillover would imply that a rebate program motivated energy efficiency purchases without ultimate program participation.

For this evaluation, we limit the definition of spillover to additional non-rebated energy efficient purchases by program participants. We expect participant spillover to be a major part of the potential Warm- and CoolAdvantage-related spillover in the market. Customers installing energy efficient units as a result of the programs are taking advantage of program rebates for major installations. It is the measures outside the purview of Warm- and CoolAdvantage that are most likely to be true spillover. For these measures, program participants represent a reasonable target for spillover questions.

First, participants were asked a series of questions summarizing their experience with energy efficient technologies and awareness of energy usage. Then they were asked if they had purchased any energy efficient improvements without a rebate. The survey records the nature of the improvements as well as a measure of the degree to which the program was influential in making that purchase.

Table 4-2 provides the spillover sequence and its associated scoring process. We assigned savings values to the energy efficiency measures purchased/installed without a rebate. The savings values were then scaled by the level of influence of the program.

Table 4-2

Spillover Sequence for Warm- and CoolAdvantage Measures

Survey #	Research Question		Question Response	Scoring for Spillover
SO5	Since purchasing the rebated [MEASURE] have you made additional energy efficiency improvements at your house WITHOUT a rebate from New Jersey's Clean Energy Program or your utility?		Yes No	Continue with sequence End sequence. No spillover.
SO6	Thinking about the biggest of these improvements, how influential was the experience of installing the [MEASURE] in motivating this additional energy efficiency improvement? On a scale of 1 to 10 where 1 means "Not at all Influential" and 10 means "Very Influential."		1 (not at all influential) to 10 (very influential)	Influence = rating/10.
SO7	What improvements did you make?		EE Measures installed without a rebate.	Measure Impact (kWh or therms)
Condition		Count	Spillover Calculation	
Spillover savings for SO5=Yes , with clear measure		$n_{SO5=Y}$	$SO_{SO5=Y}$ = Influence * Impact	
Spillover savings for SO5=No		$n_{SO5=N}$	$SO_{SO5=N} = 0$	
Spillover savings for program			$SO_{PROG} = (n_{SO5=Y}/(n_{SO5=Y}+n_{SO5=N})) * SO_{SO5=Y}$	

One of the inherent difficulties of measuring spillover is identifying the non-rebated measures that were installed or purchased. For the spillover sequence, participants were able to clearly state that they did not do any activities that qualify as spillover. Answering question SO5 with a "No" indicated no contribution to spillover.

Many participants that answered "Yes" to SO5 did not respond with a clearly defined measure. For measuring spillover, it is essential that the further energy efficient purchases were non-rebated. Since this detail is so important, it is difficult to assign any spillover to a participant that cannot explicitly identify the measure. As a result, measure savings for respondents with undefined measures were not included directly in the estimate of spillover savings. When calculating the percentage of participants with spillover, these participants with undefined measures were left out of both the top and bottom of the fraction. This is a reasonable middle ground between effectively assigning these participants full credit or no credit.

For those able to identify a specific measure installed without a rebate, we calculated average spillover savings using the values provided in Table 4-3.

Table 4-3
Measure Savings used for Spillover Calculation

Savings Type	Measure	Annual Savings	Source and Notes
Electric (kWh)	Refrigerator	75	EnergyStar.gov calculator default average difference
	Washing Machine	250	EnergyStar.gov calculator default
	Dishwasher	130	EnergyStar.gov calculator default
	Lighting	99	EnergyStar.gov calculator default
	Insulation (Cooling)	149	Cooling usage x 15% (percent from energystar.gov)
Gas (Therms)	Insulation	99	Heating usage x 15% (percent from energystar.gov)
	Windows	49	energystar.gov - 4.9 mil. Btu, assume 100k btu/therm
	Doors	16	Assume 1/3 window savings
	Water Heater	7	4% savings (Protocol equation) x 180 therms (EIA)
	Washing machine	8	EnergyStar.gov calculator default
	Furnace	101	Impact evaluation result

There is a range of approximately one to three years since participation for these participants. The average span of time between program measure installment and survey was 21 months. We used this number to annualize the spillover estimate.

5. Data

5.1 Program Tracking and Billing Data

The New Jersey BPU ordered New Jersey utilities to provide to KEMA tracking and billing data for the WarmAdvantage and CoolAdvantage Programs. A total of seven utilities provided these data for this impact evaluation.

The utilities used the tracking data to track installations of program measures. The measure level information is essential for the evaluation. In addition to capturing measure data, we used the tracking data to identify unique participants by account numbers. We then requested billing data for all participants. Tracking and billing data were then combined with weather data to create the evaluation dataset. For this kind of evaluation, the number of participants with viable data decreases with each step in the process. It is common to lose a substantial percentage of data. The following sections describe the tracking and billing data compilation process.

The tracking data for different utilities covered different years. Given the limitations in available billing data, we limited the evaluation to measures installed in program years 2005 and 2006. Billing data was requested for all participants for at least 12 months before and after program participation. Obtaining 12 months of pre- and post-program participation billing data was not possible for all participants. The final count of participating households available for billing analysis reflects participants with valid utility account numbers, some suitable billing data and a correct zip code that matched with the selected weather stations.

It should be noted that the final evaluation dataset includes all participants with some billing data. The billing analysis regressions have various requirements with regards to number of data points per participant, in the pre- or post-program period, etc. The final counts of participants actually included in the billing analyses are included in the last lines of the following tables.

5.1.1 CoolAdvantage

Four utilities participated in the CoolAdvantage Program: PSE&G, JCP&L, ACE and RECO. Program tracking data were received from all four utilities. Table 5-1 provides the counts of participants for each utility through the tracking and billing data process. A higher proportion of PSE&G and RECO participants with available billing data were not used in the billing analysis because they lacked sufficient billing records from the pre-installation period.

Table 5-1
CoolAdvantage Tracking and Billing Data Process

CoolAdvantage Data Collection Stage	Count of Households			
	ACE	JCPL	PSEG	RECO
All Participating Households in Tracking	1,665	4,161	19,235	688
Participating Households, 2005, 2006 Program Years	1,602	3,769	11,258	341
Billing Data Received from all Participating Households	1,665	3,819	10,486	270
2005, 2006 Participating Households with Billing Data	1,560	3,753	9,573	229
Final Count of Households Available for Billing Analysis	1,521	3,677	9,565	229
Final Count of Households Used in Billing Analysis	1,320	3,058	4,418	67

5.1.2 WarmAdvantage

Four utilities participated in the WarmAdvantage Program: Elizabethtown, New Jersey Natural Gas, PSE&G, and South Jersey Gas. Program tracking data were received from all four utilities. Table 5-2 provides the counts of participants for each utility through the tracking and billing data process.

Table 5-2
WarmAdvantage Tracking and Billing Data Process

WarmAdvantage Data Collection Stage	Count of Households			
	E_Town	NJNG	PSEG	SJG
All Participating Households in Tracking	883	10,723	24,000	12,789
Participating Households, 2005, 2006 Program Years	875	9,774	13,137	2,133
Billing Data Received from all Participating Households	822	5,228	14,141	5,817
2005, 2006 Participating Households with Billing Data	807	4,602	10,701	1,142
Final Count of Households Available for Billing Analysis	774	4,517	10,539	1,131
Final Count of Households Use in Water Heater Billing Analysis	157	157	2,386	18
Final Count of Households Use in Furnace Billing Analysis	442	2,498	3,063	968
Total Count of Households Used in Billing Analysis	599	2,655	5,449	986

5.1.3 Data Fields Used

Though the program used a single application form, the tracking data maintained by the utilities varied widely in data actually available to the evaluators.

For this evaluation certain fields were essential:

- Customer account
- Date of install
- Unit capacity and efficiency (or model information)
  - CAC -- Btu and SEER, or
  - Furnaces and boilers -- Btu and AFUE, or
  - Water heaters -- gallons and GAMA rating.
- Telephone number

There were additional fields included on the application that would have been useful for the evaluation, but they were not included in the tracking data for all utilities and thus could not be used. These fields included:

- New Installation vs. Retrofit
- New ductwork
- Program calculated savings
- Rebate amount

The PSE&G tracking data for CoolAdvantage was missing a greater proportion of capacity ratings than the remaining utilities. Recognizing the importance of including capacity variables in the billing analysis, we used model numbers to fill the CAC capacity field. Where program capacity data was available for some instances of a specific model number, we used the mean of the available data to fill the remaining instances with missing capacity. In addition, CAC units generally have the nameplate Btu embedded in the model number. Where necessary, we used these capacities derived from the model number to fill the missing data.

It was not possible to fill missing capacity data in all instances. The importance of capacity to the model specification meant that households with missing capacity data were not included in the regressions.

The CoolAdvantage rebate application requires substantial amounts of information related to the QIV and sizing process. This data should be collected and included in the tracking data going forward.

5.2 Tracking Data Validation

KEMA attempted to validate the data received in program tracking databases for program years 2005 and 2006.

Annual Reports for the New Jersey Clean Energy Programs provided the reported program savings. The reports provided the programs' accomplishments in minimal detail. Only aggregate Residential HVAC program (Cool- and WarmAdvantage combined) statistics were available on an annual basis. For 2005, the report included counts of the major measures.

The tracking data KEMA received for the Residential HVAC programs were incomplete with respect to key variables – particularly unit level estimated savings. This made it impossible to compare the savings represented in the tracking with the annual reported totals.

The reported 2005 measure counts give the only means of checking whether we received a complete set of tracking data. The counts from the annual report are not consistent with the count of measures for which we receive tracking data. Table 5-3 provides the measure counts from the annual report and the counts from the tracking data we received.

Table 5-3

Comparison of 2005 Reported Measure Counts with Tracking Data Counts

Measures	Annual Report Counts	Available Tracking Data
Furnaces/Boilers	9,295	9,658
Central AC/Heat Pumps	17,710	9,141
Water Heaters	3,307	3,004
ECM		168
All Measures	30,312	21,971

KEMA received tracking data for most of the claimed furnaces and water heater measures. KEMA only receive tracking data for just over 50 percent of the claim central air conditioner and heat pump measures. As further evidence that we did not receive some of the 2005 data, the tracking data measure counts for 2006 increased by 14 percent while the annual report shows a 4 percent decrease in the number of participants.

Because of nature of the data we received, the due diligence portion of the ex-post evaluation is limited to program participants for whom data was provided. We were not able to confirm participation beyond program tracking data. Thus these records determined the program participant counts to which we applied estimates of per-participant savings. Given the large number of participants included in this evaluation, the per-participant impact findings should be appropriate for average Residential HVAC participants.

5.3 Weather

The weather variables included in the billing regressions are degree days based on daily average temperature. We use daily average temperature defined as the average of the daily minimum and maximum temperatures. The equation used is

Daily Average Temperature = (daily maximum + daily minimum)/2

Weather variables in a regression of this sort are always a proxy for the specific weather conditions faced at the household site. Recognizing the variation in New Jersey weather from shore areas to the highlands and from north to south, we opted to use four different weather series to describe the weather conditions facing households. Table 5-4 provides the list of counties matched with the National Oceanic and Atmospheric Administration (NOAA) weather station from which data was collected.[18]

Table 5-4
Weather Stations used for New Jersey Counties

Weather Station (WBAN number)	New Jersey Counties
Atlantic City (93730)	Atlantic
	Cape May
	Monmouth
	Ocean
Newark (14734)	Bergen
	Essex
	Hudson
	Middlesex
	Passaic
	Union
Philadelphia (13739)	Burlington
	Camden
	Cumberland
	Gloucester
	Salem
Sussex County (54793)	Hunterdon
	Mercer
	Morris
	Somerset
	Sussex
	Warren

For reporting results it is common to use degree days based on a typical year temperature series rather than actual temperatures. For this impact evaluation we use the average degree days over the years 2000 through 2007.

5.4 Participant Survey

The participant survey served multiple purposes:

[18] We matched counties and weather stations based on an overview of New Jersey's climate from the Office of the New Jersey State Climatologist (http://climate.rutgers.edu/stateclim/?section=uscp&target=NJCoverview) and proximity with available weather stations.

- Responses used to estimate free ridership and spillover
- Mean estimates of population characteristics (percent of participants installing a new unit)
- Information on other activities that might have affected usage during the evaluation period

5.4.1 Survey Sample Design

The proposed size of the participant sample was 300 respondents. The sample was stratified by utility and measure type: heating (furnace and boilers), cooling (CAC and heat pumps) and water heat. Water heaters, as the measure with both the lowest counts and lowest savings, were allocated 30 respondents while the remaining respondents were allocated equally to the heating and cooling strata. Within the measure groups, the sample was allocated to the utilities approximately proportional to size.

The survey sample was pulled from the analysis dataset. That is, a participant had to meet the requirements listed above to be included in the survey sample. All participants with a measure installed were included in the frame for that measure. To facilitate survey completes, the phone survey was designed to focus on only a single measure regardless of whether multiple measures were installed. Just over ten percent of the sample installed multiple measures. All but two percent were a combination of space heating and cooling measures.

Table 5-5 provides the sample targets and the number of completed surveys.

Table 5-5
Sample Targets and Completes

Measure	Utility	Participants	Optimal Sample Size	Final Sample Target	Completed Surveys
Furnace	NJNG	3487	55	54	54
	PSEG	3367	53	53	55
	SJG	1139	18	18	18
	E_Town*	622	10	10	11
	Total	8615	135	135	138
AC	ACE	1452	21	21	21
	JCPL	3218	47	47	47
	PSEG	4545	66	65	65
	RECO	87	1	2	2
	Total	9302	135	135	135
WH	PSEG	2545	25	24	24
	NJNG	289	3	6	3
	SJG	34	0	0	1
	E_Town*	233	2	0	2
	Total	3101	30	30	30

*Sample was pulled before billing data was received from E_town so these numbers are from the tracking data

5.4.2 Fielding the Survey

KEMA subcontracted with Braun Research to complete the survey fieldwork. The survey house used computer aided telephone interviewing technology to complete the targeted number of interviews. When finished, Braun supplied KEMA with the raw data reflecting the results from the completed surveys. Because the majority of the survey questions were designed for the support of the billing analysis and free ridership and spillover calculations and not for general interest, we did not request banners. Results for survey questions of interest are included in the results section.

6. Results

This section reports the impact evaluation results. This section also reports on changes recommended to the Protocols based on the results of the impact evaluation.

The impact evaluation results are limited to electric cooling savings and gas heating savings. These are the primary sources of savings for the two programs and the kinds of savings for which the proposed billing analysis approach is best suited.

A full water heating billing analysis was conducted but no usable results were generated. The analysis failed because water heating savings are relatively small and difficult to separate from a household's base load using billing analysis.

6.1 Gross Impacts

This section presents the gross impact results. For CoolAdvantage, we report gross ex-post impact results using the baseline efficiencies in place at the time of the 2005 and 2006 programs. We also present results based on the same 2005/2006 data but using the baseline efficiencies in effect now for the program. For WarmAdvantage furnaces and boilers there has been no change in the baseline efficiencies but we recommend a change in baseline (typical) capacity used in the savings equation. We present results for the Protocols as they presently exist as well as with the proposed baseline capacity change.

6.1.1 Billing Regression Results

The raw billing regression results provide the basis for both the impact evaluation and the review of the Protocol equations.

The model statistics for the post-program and the pre-post billing models are provided in tables Table 6-1 and Table 6-2.

Table 6-1
Post-Program Billing Model Statistics

Model	Number of Participants	Number of Observations	R^2
Cooling	8,793	135,931	0.83
Heating	6,290	71,689	0.78
Water Heating	2,488	34,349	0.68

Table 6-2

Pre-Post Billing Model Statistics

Model	Number of Participants	Number of Observations	R^2
Cooling	8,863	196,694	0.79
Heating	6,896	114,417	0.62
Water Heating	2,659	51,642	0.69

The key coefficient estimates for the cooling post-only billing model are provided in Table 6-3. The heating degree day coefficient is not used for this evaluation but is important for properly specifying annual electric usage. The cooling degree day/ Capacity interaction is highly statistically significant. As noted earlier, this combined variable so completely explains cooling related load that the non-interacted cooling degree day variable was dropped from the regression.

Table 6-3

Post-Program Cooling Billing Regression Key Coefficient Estimates

Variable	Description	Estimate	Standard Error	T-Value	P Value
hdd64	Heating degree days, base 64°F.	0.1389884	0.0191814	7.25	<.0001
cdd64*Btu	Cooling degree days, base 64°F x Capacity (Btu)	0.00002802	0.00000058	48.71	<.0001

The key coefficient estimates for the cooling pre-post billing model are provided in Table 6-4.

Table 6-4

Pre-Post Cooling Billing Regression Key Coefficient Estimates

Variable	Description	Estimate	Standard Error	T-Value	P Value
hdd64	Heating degree days, base 64°F.	0.14703718	0.0152687	9.63	<.0001
cdd64	Cooling degree days, base 64°F.	1.47812556	0.03611127	40.93	<.0001
post*btu	Post-Installation indicator x Capacity (Btu)	0.00001943	0.00000425	4.57	<.0001
cdd64*post	Cooling degree days, base 64°F. x Post-Installation indicator	-1.53251943	0.03524912	-43.48	<.0001
cdd64*post*btu	Cooling degree days, base 64°F. x Post-Installation indicator x Capacity (Btu)	0.00002704	0.00000072	37.34	<.0001

The key coefficient estimates for the heating variables are provided in Table 6-5. Both the heating degree day coefficient and the heating degree day/ capacity interaction term are highly statistically significant. Cooling degree days were not included in the gas billing regression from the start.

Table 6-5
Post-Program Heating Billing Regression Key Coefficient Estimates

Variable	Description	Estimate	Standard Error	T-Value	P Value
hdd58	Heating degree days, base 58°F.	0.114915836	0.00277468	41.42	<.0001
hdd58*Btu	Heating degree days, base 58°F. x Capacity (Btu)	0.00000091	0.00000002	48.98	<.0001

The key coefficient estimates for the heat pre-post billing model are provided in Table 6-6.

Table 6-6
Pre-Post Heating Billing Regression Key Coefficient Estimates

Variable	Description	Estimate	Standard Error	T-Value	P Value
hdd58	Heating degree days, base 64°F.	0.194254399	0.002677	72.56	<.0001
post*Btu	Post-Installation indicator x Capacity (Btu)	-0.000005141	0.0000003	-17.07	<.0001
hdd58*post	Cooling degree days, base 58°F. x Post-Installation indicator	-0.065248135	0.00312153	-20.9	<.0001
hdd58*post*Btu	Cooling degree days, base 58°F. x Post-Installation indicator x Capacity (Btu)	0.000000755	0.00000003	28.93	<.0001

6.1.2 Protocol Equation Inputs

The gross impact results make use of the same basic engineering equations as those presented in the Protocols. All equation inputs are based on participation data from program years 2005 and 2006. The inputs used are median efficiencies and sizes of the units in the program population at that time. Table 6-7 and Table 6-8 provide the input values for the basic impact equations.

Table 6-7
CoolAdvantage Impact Equation Inputs

Equation Inputs	Source	Value
Baseline Effciency (SEER) for Ex-Post Impact	2004 Prototcols	11.0
Baseline Effciency (SEER) future Program performance	2007 Prototcols	13.0
Median Participant Unit Rating (SEER)	2005-2006 Tracking Data	14.0
Median Participant Unit Capacity (Btu)	2005-2006 Tracking Data	35,000

The CoolAdvantage inputs include the baseline SEER values appropriate for the ex-post impacts (2004) as well as the new 2007 baseline SEER. The baseline increase substantially lowers the efficiency gain for which the program can take credit.

Table 6-8
Heating Impact Equation Inputs

Equation Input	Measure	Value	Source
Baseline Efficiency (AFUE) for Ex-Post Impact	Furnace	0.80	2004 and 2007 Protocols
	Boiler	0.83	
	Combined	0.80	
Typical Unit Output Capacity (Btu)	Combined	91,000	2007 Protocol
Median Participant Unit Efficiency Rating (AFUE)	Furnace	0.93	2005-2006 Tracking Data
	Boiler	0.92	
	Combined	0.93	
Median Participant Unit Capacity (Btu)	Furnace	80,000	2005-2006 Tracking Data
	Boiler	114,000	
	Combined	82,449	

The WarmAdvantage inputs are a combination of the boiler and furnace values. The combined values are a program population weighted mean of the individual measure median values.

We recommend that the qualifying unit capacity replace the typical unit capacity as the baseline unit capacity. For the second set of heating savings results the combined median qualifying unit capacity is used for both baseline and qualifying units.

6.1.3 Weather inputs

The reported results are based on the average cooling and heating degree days for the years 2000 through 2007. Table 6-9 provides the average degree days for the base temperatures used in the final billing models. It also shows the degree days for that base temperature calculated from actual temperatures for the same eight years.

Table 6-9
Normal and Actual Degree Day Temperatures for NJ Program Area

	Year	Cooling Degree Days (Base Temperature = 64°)	Heating Degree Days (Base Temperature = 58°)*
Actuals	2000	1,004	3159
	2001	1,279	3759
	2002	1,467	2746
	2003	1,149	3953
	2004	1,162	3540
	2005	1,474	3588
	2006	1,286	3104
	2007	1,393	3257
2000 to 2007 Average		1,277	3,388

*Year 2000 HDD is winter 1999-2000 HDD, etc

The billing records included in the billing models were from 2005 through 2007, with an emphasis on the latter two years. These two latter years, in particular, were not extreme years with respect to CDD or HDD. The billing models control for degree day differences but have a limited capability of controlling for atypical usage patterns motivated by abnormally warm or cold seasons. Given these degree day levels, it's unlikely this was an issue for these models.

6.1.4 Cooling Efficiency-Related Savings Results

Table 6-10 provides the gross results of the post-only CoolAdvantage billing analysis. The table provides a benchmark estimate based on the 2007 Protocol values. It also provides ex-post impact estimates for three different levels of QIV savings. All of these results are relative to a standard baseline SEER of 11. The savings estimates with the increased SEER baseline of 13 are presented in Table 6-11.

Table 6-10
Gross 2005/2006 CoolAdvantage Ex-Post Per-Unit Impact Estimates Baseline SEER=11

Source for Hour (EFLH) Estimate	Post-Program Cooling Usage (kWh)	Effective Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%)	Impact of Efficiency Improvement (kWh)	Combined QIV/Sizing Savings Percentage	QIV/Sizing Savings as Percentage of Usage	Impact of Proper Sizing and QIV (kWh)	Total CAC or Heat Pump Cooling savings (kWh)
Protocols	1,500	600		409	19.3%	23.8%	358	767
Impact Evaluation	1,252	501	17	341	0.0%	0.0%	0	341
					8.4%	9.2%	115	456
					19.3%	23.8%	298	640

The Protocol-based results use the 2007 Protocol EFLH value of 600 hours and award the full 19.25 percent proper sizing/QIV savings. Based on the program SEER and capacity, the Protocol EFLH implies cooling usage of 1500 kWh (Equation 3). The efficiency savings relative to the 2005/2006 standard baseline SEER of 11 are 409 kWh (Equation 1). The total savings, including 358 kWh awarded for proper sizing/QIV, are 767 kWh. These results do not account for either free ridership or spillover.

The post-only billing analysis provides an estimate of participant CAC usage in the post-program period of 1,252 kWh. This produces an estimate of 501 hours for cooling EFLH with a 90 percent confidence interval of plus or minus 17 hours (Equation 32). This is a strongly significant result that is well below the Protocol EFLH estimate of 600 hours. Energy efficiency impacts are estimated at 341 kWh (Equation 33). QIV/sizing savings ranging from 0 to 298 kWh bracket the range of potential QIV/sizing savings. The research supports QIV/proper sizing of 8.4 percent savings when proper installation and sizing are applied to a typical (non-QIVed) unit. That amounts to 9.2 percent of the reported post-program cooling usage (Equation 11). The total impact ranges form 341 to 640 kWh depending on the level of QIV/sizing savings. The total impact with the recommend QIV/sizing level is 456 kWh.

Table 6-11 presents the identical results except that the standard efficiency baseline is set at the current higher level of SEER 13.

Table 6-11
Gross 2005/2006 CoolAdvantage Ex-Post Per-Unit Impact Estimates
Baseline SEER=13

Source for Hour (EFLH) Estimate	Cooling Usage (kWh)	Effective Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%)	Impact of Efficiency Improvement (kWh)	Combined QIV/Sizing Percentage	QIV/Sizing Savings as Percentage of usage	Impact of Proper Sizing and QIV (kWh)	Total CAC or Heat Pump Cooling savings (kWh)
Protocols	1,500	600		115	19.3%	23.8%	358	473
Impact Evaluation	1,252	501	17	96	0.0%	0.0%	0	96
					8.4%	9.2%	115	211
					19.3%	23.8%	298	395

The Change in baseline SEER drops the impact evaluation estimate of efficiency-related savings from 341 kWh to 96 kWh. This is a reduction of over 70 percent. Using the 2007 Protocols, savings estimates for the current program will reflect this lower level of efficiency-related savings. The savings due to proper sizing and QIV do not change. As a result, these installation-related savings play a relatively bigger role in the savings generated by the program.

Table 6-12 provides overall impact estimates from the pre-post billing analysis. Because the existing unit SEER is unknown we produce estimates across a range of replaced unit SEERs.

The program only gets credit for the difference between standard and efficient. Therefore the closer the assumed SEER value comes to the baseline value of 11, the more of the pre-post billing model change in usage is attributed to the program. The EIA Residential Energy Consumption Surveys from 1978 and 1997 put average population SEER at 7.34 and 10.66[19]. It is possible units being replaced in 2005 and 2006 could have had an average existing SEER as high as 10.

Table 6-12
Pre-Post Billing Analysis Total Cooling Savings Assuming Replaced Unit SEER

Assumed SEER of Replaced Unit	Total CAC or Heat Pump Cooling savings from Pre-Post Billing Analysis (kWh)
8.0	362
8.5	420
9.0	489
9.5	574
10.0	679
10.5	815
11.0	996

The Pre-Post billing analysis provides additional perspective to the Post-only impact estimates. In the most basic sense, the pre-post estimate confirms the general magnitude of the savings estimate from the post-only model. With a SEER of 10, the pre-post billing model impact estimate (679 kWh) has a similar overall magnitude to the largest post-only billing analysis impact estimate with the full Protocol QIV savings (640 kWh).

There are two more specific issues into which the pre-post estimate provides insight. The first issue is determining the appropriate level of sizing/QIV energy savings. As discussed in section 4.1.1, the pre-post result provides a clear upper bound to the combined efficiency-related and sizing/QIV savings. If the pre-post impact estimate only included efficiency and QIV savings then the pre-post impact estimate would not rule out the high level of sizing/QIV savings in the 2007 Protocols. Importantly, though, the pre-post result also includes any possible degradation that was in evidence in the replaced unit's pre-program usage. Any degradation at the existing unit lowers the savings left to attribute to QIV savings below the Protocol QIV saving levels.

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[19] Trends in Residential Air-Conditioning Usage from 1978 to 1997 URL: http://www.eia.doe.gov/emeu/consumptionbriefs/recs/actrends/recs_ac_trends.html

Furthermore, it is more likely the existing unit SEER is below 10 than above it. If the existing unit SEER is lower than 10 then the savings attributable to sizing/QIV savings will also be lower.

The 8.4 percent sizing/QIV-related savings represents a reasonable middle ground. This level of sizing/QIV savings allows for flexibility in the existing unit SEER and apportions a reasonable amount of the pre-post savings to existing unit degradation. This value falls in the middle of the values offered by available research.

The second issue into which the pre-post estimate provides insight is the question of take-back. Take-back would artificially inflate post-program usage. If take-back were occurring, the pre-post billing analysis impact estimate would be lower than the post-only impact estimate. The presence of sizing/QIV savings complicates the issue. However, the SEER 10 pre-post impact estimate is larger than any of the post-only impact estimates. Moreover, the efficiency-improvement savings are only 341 kWh, well below the range of pre-post impact estimates.

Ultimately, there is little evidence in the cooling pre-post impact estimate that the cooling impact should be smaller than that provided by the post-only model. As a result, there is little evidence of cooling take-back.

The participant survey provides additional evidence on this question. Participants were asked to rate how frequently they used their CAC before and after the program. Of 95 respondents who replaced existing CAC units, 5 respondents, or just over five percent, indicated running their CAC more after the program than before. All but one of these respondents increased their amount of cooling incrementally, so the actual average take-back would be lower than five percent.

The post-only impact estimate is an empirically-based estimate of CoolAdvantage cooling savings. To the extent the cooling pre-post billing analysis succeeds, it lends support to the post-only billing analysis impact estimate. The incidence of take-back appears to be low for cooling installations and there is no evidence supporting it in the comparison of pre-post and post-only billing analysis impact estimates.

6.1.5 Heating Efficiency-Related Savings Results

Table 6-13 presents the gross WarmAdvantage impact results. These results compare 2005/2006 program impacts based on the Protocol EFLH with the impact estimates from this evaluation's estimate of equivalent full load hours (EFLH). If the 2007 Protocols are not revised, these same results will continue to be applicable.

Table 6-13

Gross 2005/2006 WarmAdvantage Ex-Post Per-Unit Impact Estimates

Baseline Capacity = 91,000 Btu

Source for Hour (EFLH) Estimate	Post-Program Usage (Therms)	Equivalent Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%, Hours)	Baseline Capacity	Impact Relative to Standard (Therms)
Protocols	860	965	[redacted]	91,000	235
Impact Evaluation	648	727	13		177

The 2007 Protocol-based impact estimate uses a heating EFLH of 965 hours. This implies a post-program gas usage of 860 therms. The efficiency-related savings, assuming the 2007 Protocol typical baseline unit capacity of 91,000 Btu, is 235 therms.

The ex-post heating billing analysis estimates post-program usage at 648 therms. This usage estimate directly motivates an estimate of EFLH of 727 hours with 90 percent confidence interval of plus or minus 13 hours (Equation 43). This is a strong statistical result substantially below the Protocol EFLH. The estimate of 727 EFLH produces an impact estimate of 177 therms based on the same baseline unit capacity assumptions (Equation 44).

Table 6-14 reproduces the same results with the recommended change to the baseline unit capacity (Equation 45). The billing analysis savings result drops from 177 therms to 100 therms. Using the larger, “typical” unit baseline implies a substantial average unit downsizing for which there is no evidence.

Table 6-14

Gross WarmAdvantage Per-Unit Impacts Using Qualifying Unit Capacity for Baseline

Source for Hour (EFLH) Estimate	Post-Program Usage (Therms)	Equivalent Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%, Hours)	Baseline Capacity	Impact Relative to Standard (Therms)
Protocols	860	965	[redacted]	82,449	132
Impact Evaluation	648	727	13		100

The role of the heating pre-post billing analysis is more limited than cooling pre-post billing analysis. On the one hand, many of the issues that complicated the cooling impact estimates are not issues with the heating measures as presently promoted. There are no installation-related savings connected with the installation of furnaces or boilers[20]. There are also fewer ways for a furnace's efficiency to degrade over time.

On the other hand, furnace replacers are more likely to increase the capacity of the furnace to account for increased floor space. The survey indicates that almost 10 percent of gas furnace replacers increased the size of their unit[21]. This kind of increased capacity is difficult to control for in the pre-post billing analysis process. In particular, in a billing analysis framework, increased usage from increased capacity is indistinguishable from increased usage due to take-back. The difference is important because the increased capacity should not be allowed to diminish the program's savings while take-back should.

Table 6-15 provides the total heating savings estimated by the pre-post heating billing model. The pre-post conversion assumes the same capacity before and after, so these results compare to the results in Table 6-14.

Table 6-15
Pre-Post Billing Analysis Total Heating Savings Assuming Replaced Unit AFUE

Assumed AFUE of Replaced Unit	Total Furnace or Boiler Heating Savings from the Pre-Post Billing Analysis (Therms)
0.60	33
0.65	42
0.70	55
0.75	76
0.80	113

The table provides the total heating savings given the assumed replaced unit efficiency. As with CAC, it is impossible to know the actual efficiency of the units replaced by the program but it is possible to identify a reasonable range. It is likely the average replaced unit AFUE is 0.7 or below. Replaced heating units can be 30 years old or older and higher efficiency models were less available many years ago. For this discussion we will assume an AFUE of 0.7.

[20] Duct sealing is now included in the Protocols, but it was not in place in 2005 and 2006.
[21] Only 2 percent of CAC installers said they increased the amount of cooled floorspace.

The 0.7 AFUE, pre-post impact estimate of 55 therms compares to the post-only impact estimate of 100 therms. This is a 45 therm reduction in savings. There are multiple possible explanations for this result.

Reduced savings could be explained by poorly characterized baseline usage. Efficiency savings are relatively small, on the order of 15 percent of usage, so savings are particularly sensitive to the estimate of baseline usage. The pre-program data is thin compared to the large amount of post-program data available. This could explain the baseline not representing the full extent of pre-program usage.

This reduction in savings could also be explained by an inflation of post-program usage. The reduction in savings would be consistent with a post-program usage inflated by approximately 40 therms or 6 percent. This increase in post-program usage could be explained by either increased capacity or take-back or both.

Incremental increases in capacity by a small subset of participants will explain one or two percentage points of the increased post-program usage[22]. Take-back would explain the remainder. An average increase in thermostat set-point of just one degree across all participants would represent a substantial but not unrealistic level of take-back. According to the post-only billing analysis regressions, a set-point increase of one degree would increase post usage by about approximately 33 therms. In combination, these two factors could account for the lower impact estimates produced by the pre-post billing analysis.

The post-only impact estimate of WarmAdvantage heating savings is an empirically-based estimate. The estimate represents a substantial downward adjustment on expected Program savings. If the pre-post billing analysis is sound, the pre-post impact estimate indicates that this reduced level of savings may still be artificially inflated due to not taking into consideration participant take-back. On the other hand, the pre-post impact estimate could simply be an artifact of the difficult data gathering process for this analysis. Unfortunately, the survey did not ask questions about changes in heating set-points before and after the program.

Given the uncertainty surrounding the pre-post model impact estimate, we believe the post-only impact estimate is still the most reliable estimate of program savings. The pre-post estimate does, however, add credence to the possibility of take-back effects in a program like this. If

[22] A ten percent increase in heated area by ten percent of the population will increase the overall heated space by only one percent. Just under ten percent of survey respondents indicated an increase in heated space.

future evaluations use a billing analysis approach, they should emphasize collecting sufficient pre-program data to allay concerns over the estimate of baseline usage. In addition, heating participants should be questioned over set-point changes.

6.1.6 Impact Analysis Implications for Protocol Equations

The impact analysis has important implications for the central Protocol equations for heating and cooling savings.

In both cases the empirically-based estimate of equivalent full load hours (EFLH) is well below the value presently used in the Protocols. For cooling the impact evaluation estimate of EFLH is 17 percent below the original 600 hour Protocol equation estimate, or 501 hours. The review of the Protocol heating equations indicated that the Protocol EFLH value of 965 hours substantially overstated the heating EFLH. The impact evaluation estimate of heating EFLH is 25 percent below the 965 hour Protocol equation value, or 727 hours. These billing analysis results are the basis for recommended changes in the Protocols.

In addition, the pre-post cooling billing model provides a framework within which to consider the savings from proper sizing and quality installation. The model does not give an alternative level of savings, but does suggest that the present levels are too high. Combining this evidence with secondary source research leads us to recommend a lower installation-related level of energy savings, 8.4 percent savings relative to standard equipment (9.2 percent of participant usage). This in turn requires a lowering of the demand related savings to below this level, though we do not specify a new level. The Market Assessment recommended lowering the demand savings value to 2.9 percent (3 percent of participant demand). This level would be consistent with the proposed energy savings level.

6.2 Free Ridership

This section summarizes the free ridership results. Table 6-16 provides the free ridership levels for the three major measure groups. The free ridership level for CAC and heat pumps is 0.48. This indicates that 48 percent of Program savings are not attributable to the program. The free ridership level for furnaces and boilers is 0.45.

Table 6-16
Free Ridership Levels

Measure	Free Ridership
Central Air Conditioners and Heat Pumps	0.48
Furnaces and Boilers	0.45
Water Heater	0.33

These free ridership results are primarily driven by the first question in the free ridership sequence -- Was the participant likely to have installed the same level of energy efficiency without the program rebate. For all three measures, close to 40 percent of survey respondents said they were very likely to have installed the same level of energy efficiency without the program rebate. These participants are 100 percent free riders after the first question. Additional participants indicated a partial level of free ridership on the first question.

The second question looked for evidence of acceleration of the installation as a result of the program. Across all levels of initial free ridership, as determined by first question in the sequence, acceleration reduced initial free ridership levels, on average, by 27.5 percent. Those participants with 100 percent free ridership after the first question were assigned this level of acceleration[23]. After the complete free ridership sequence, less than 30 percent of respondents answered the free ridership series so as to receive a score indicating no free ridership.

An important factor in explaining free ridership levels is the degree of penetration of the energy efficient measure in the program's geographical area. Higher penetration will result in higher levels of free ridership for that program measure. The New Jersey HVAC Baseline Study from 2001 concluded that New Jersey was slightly above the national average in terms of both energy efficient cooling and heating penetration. This provides some explanation for these moderately high levels of free ridership.

6.3 Spillover

This section summarizes the results pertaining to program spillover. This evaluation produced two different kinds of results related to spillover:

[23] Individual acceleration rates for these participants were not captured in the survey.

- Answers to general question regarding issues related to spillover -- confidence in energy efficient technologies and resulting energy savings, greater awareness of energy usage and new relationships with contractors or dealers working with energy efficiency.
- Savings of actual non-rebated energy efficient improvements.

The first set of results give a qualitative feel for the effect of the programs on likelihood to purchase other energy efficient measures. Improved awareness of and confidence in energy efficient products are necessary conditions for improving sales of energy efficient products.

The second results produce the quantitative measure of program spillover. The process for calculating spillover from these questions is discussed in the methods section.

6.3.1 Confidence in Energy Efficient Technologies, Etc.

Table 6-17 presents the results from the introductory spillover questions. A substantial percentage of participants are more confident about the reliability and energy saving potential of energy efficient technologies. Almost three quarters are more aware of their energy usage or costs. There's also evidence that the program introduced the participants to new contractors or dealers. The program had an active part in connecting 42% of participants with a contractor or dealer that works with energy efficient products.

Table 6-17
Spillover Question results

Survey #	Survey Question	Percent Answering "Yes"
SO1	As a result of installing the energy efficient [MEASURE], do you have more confidence about the energy savings that can result from installing energy-efficient technologies?	89.1%
SO2	Are you more confident about the reliability of energy-efficient technologies?	86.2%
SO3	Did making these improvements introduce you to new installation contractors or equipment dealers?	42.0%
SO4	As a result of your participation in this program, are you more aware of your household energy usage or costs?	72.5%

6.3.2 Spillover Savings

Spillover as a percentage of impact is based on per-participant spillover savings calculated from claimed non-rebated energy efficient improvements. The result is a per-participant estimate of savings motivated by the program above and beyond the impacts for rebated measures. Table 6-18 provides the results at important steps in the spillover process.

Table 6-18
Per-Participant Spillover Saving by Measure and Savings Type

Savings Type	Program Measure	Participants with Spillover Purchase: Average Savings	Participants with Spillover Purchase: Spillover Savings Influenced by Program	Percentage of Participants with Spillover Purchase	Average Per-Participants Spillover Savings	Average **Annual** Per-Participants Spillover Savings*
kWh	Central Air Conditioner	155	115	18%	21	12
	Furnace	124	73	22%	16	9
	Water Heater	76	38	9%	3	2
Therms	Central Air Conditioner	73	50	28%	14	8
	Furnace	76	40	22%	9	5
	Water Heater	75	43	22%	10	6

*Time between average installation data and fielding of survey was 21 months. To annualize, divide by 1.75.

6.4 Survey Results Related to Measure Lives

Three questions were asked on the participant survey related to satisfaction with the installed measure. The first two asked if the measure was working properly and whether the respondent was satisfied with the performance. These two questions were a lead up to the question that specifically pertains to measure lives. The question asks, “Do you have any concerns with the new [measure] such that you would consider replacing it in the next 10 years?” The results from this single question, presented in Table 6-19, provide insight into one important cause of non-retention – consumer dissatisfaction leading to early replacement. Customer dissatisfaction is the most likely cause of non-retention for measures with EULs greater than 10 years.

Table 6-19
Percent Considering Replacement Due to Concerns

Measure	Percent with "Concerns such that you would consider replacing (measure) in the next 10 years".
Central Air Conditioner	2.3%
Furnace	3.7%
Water Heater	3.4%

The results presented in Table 6-19, while not zero, do not represent unexpected levels of dissatisfaction. Only some subset of these dissatisfied installers will actually act on their dissatisfaction. These results do not indicate a need to adjust accepted EULs for the Warm- and CoolAdvantage measures.

6.5 Overall Program Impacts

Three previous sections presented the gross impact, free ridership and spillover results. This section combines these three results.

In the past, the Warm- and CoolAdvantage Programs have calculated program savings using the assumption that free ridership equaled spillover. This approach is convenient as it avoids the difficult process of measuring free ridership and spillover. The evidence gathered for this report, however, does not support the assumption of net zero free riders and free drivers. The measures considered from both programs have free ridership levels substantially above the identified spillover.

Table 6-20 and Table 6-21 combine the impact results produced for this ex-post evaluation with the estimated free ridership and spillover. These tables only includes the measure savings for Warm- and CoolAdvantage Program that we were able to confirm through our billing analyses -- that is, CAC-related cooling savings and furnace and boiler heating related savings. These savings should represent the majority of the savings generated by the program.

Table 6-20

Electric Impacts from Cooling Measures, Protocol Vs. Impact Evaluation

Fuel	Year	Per-Unit Impact (MWh)	Tracking Data Number of units*	Gross Impact (MWh)	(-) Free Ridership (MWh)	(+) Spillover (MWh)	Percentage of Gross Savings: Free Ridership	Percentage of Gross Savings: Spillover	Net Impact (MWh)
Protocol	2005	0.767	9,141	7,011					7,011
	2006		9,821	7,533					7,533
Impact Evaluation	2005	0.456	9,141	4,168	1,981	194	48%	5%	2,381
	2006		9,821	4,478	2,129	218		5%	2,567

* Count of units is from the tracking data provided to the evaluation by the utilities.

Table 6-21

Gas Impacts from Heating Measures, Protocol Vs. Impact Evaluation

Fuel	Year	Per-Unit Impact (1000 therms)	Tracking Data Number of units*	Gross Impact (1000 therms)	(-) Free Ridership (1000 therms)	(+) Spillover (1000 therms)	Percentage of Gross Free Ridership	Percentage of Gross Spillover	Net Impact (1000 therms)
Protocol	2005	0.235	9,658	2,270					2,270
	2006		11,363	2,670					2,670
Impact Evaluation	2005	0.100	9,658	966	434	122	45%	13%	654
	2006		11,363	1,136	511	136		12%	762

* Count of units is from the tracking data provided to the evaluation by the utilities.

The gross impact results represent an empirically-based annual savings estimate. The per-unit impacts used for this table are based on 2005 and 2006 program data. The ex-post impact evaluation electric (cooling) savings estimate of 456 kWh per participant is based on the baseline in place during the 2005/2006 programs (SEER 11) and the revised estimate of proper sizing and QIV energy savings. The ex-post gas savings estimate is based on the recommended baseline output capacity (baseline capacity same as qualifying rather than "typical"). The gross impact results are measured with respect to a standard installation baseline. Thus they reflect one important aspect of a "net" savings estimate.

The number of units comes from the tracking data made available by the utilities. The number of units could only be checked against aggregate program statistics for 2005. This comparison indicates that we did not receive tracking data for a substantial number of CAC installations in 2005. Further validation of the 2005/2006 tracking data was not possible with the available data and thus was not a primary focus of this report. These numbers are primarily used for illustrative purposes.

The free ridership result represents the portion of the program impacts that would have happened in the absence of the program. This amount is removed from gross impact value to get program savings net of free ridership. Free ridership is calculated by applying the free ridership percentage to the gross savings.

Spillover is defined as the energy savings from additional sales of energy efficient measures motivated in some way by the program but not rebated. This amount is added to gross impact values to get program savings that include spillover savings. Both heating and cooling measures generate both electric and gas spillover. Electric spillover is the total spillover generated by both cooling and heating measures in the program year. The annualize per-participant spillover reported in Table 6-18 is combined with participant counts from the two programs to generate annual estimates of electric and gas spillover.[24]

The final net impact estimate is the gross impact net of both free ridership and spillover. The Protocol-based estimate of net savings is the same as the gross savings reflecting the assumption of zero net free ridership and spillover.

[24] This evaluation did not generate new estimates of water heat savings. Free ridership and spillover estimates were calculated. For the program median tank size and efficiency the Protocols estimate savings of 7.5 therms. Free ridership is 33 percent, while spillover is 80 percent. This gives a net combined spillover rate of 47 percent. The high level of spillover is a function of the small program savings.

7. Conclusion

The purpose of this report is twofold:

- To offer recommendations for revisions to the savings calculation Protocols so that going forward the calculations using these Protocols provide (more) accurate statements of savings accomplishments, and
- To provide a retrospective assessment of program accomplishment, as part of a due diligence review of past utility program effectiveness on behalf of ratepayers.

The billing analysis performed for this report provides the retrospective assessment of the key program measures. It also provides an empirical basis for recommendations for the most important Protocol equation inputs.

The results in this report present a baseline impact estimate based on the 2007 Protocols along with ex-post billing analysis results reflecting all recommendations to the Protocols. The gross cooling savings impacts are revised down due to lower EFLH and recommended lower installation-related proper sizing and QIV savings factors. The two changes lower cooling savings to 456 kWh per unit when the 2005/2006 protocol baseline of SEER 11 is used. Starting in 2007, the standard baseline changed to SEER 13 and this will further reduce savings to 211 kWh annually.

The change in Federal standards for CAC efficiency from SEER 11 to SEER 13 represents a major change for CAC programs like CoolAdvantage with regards to estimated savings. With the new baseline, overall savings are lower and the sizing and installation savings account for a larger percentage of those savings. There is, however, little consensus among researchers as to the actual levels of energy and demand savings from these improvements. This report, in keeping with its stated purpose, focuses on recommendations to address the challenge of estimating savings from installation-related improvements.

The WarmAdvantage gross ex-post results also find lower savings. Once again, the billing analysis-based EFLH is below the value used in the Protocols. Accounting for this change lowers the gross savings by 25 percent to 177 therms. A further recommendation, using equal capacities for baseline and qualifying units in the Protocol savings equations, lowers the gross savings another 33 percentage points to 100 therms. The gross ex-post impact estimate is 57 percent below the present Protocol level. Beyond this, there is some evidence that participant take-back is occurring that, if confirmed, would further lower the savings attributable to the savings.

Because the recommended changes to the gas heating Protocol are changes to the savings calculation not changes to Federal standards, program changes are not necessarily in order. The baseline AFUE is higher than federal minimum standards and may be above typically replacement unit AFUE. The program could set baseline AFUE lower given evidence of lower typical replacement unit AFUEs.

This report provides a review of the savings algorithms for Warm- and CoolAdvantage Programs. The review assesses the appropriateness of the savings equations and the input parameters provided in the 2007 Protocols. The review draws on findings on operational parameters from the billing analysis conducted for this evaluation on recent program participants, as well as using additional secondary source research. Key recommendations include:

- Adopt the impact evaluation estimates of Equivalent Full Load Hours (EFLH) for heating and cooling, 727 and 501 hours, respectively.
- Re-evaluate the 2007 Protocol proper sizing and QIV factors. Going forward, these factors will determine the majority of program cooling related savings. The billing analysis supports a maximum energy savings factor (combined proper sizing and quality installation verification) of 9.2 percent of installed usage. Installation-related demand savings cannot be estimated from the billing analysis. However, Demand savings should not be greater than energy savings. In the absence of better evidence, the demand savings factor should also be set at 9.2 percent of installed demand.
- Adjust installation-related factors (proper sizing, QIV or duct sealing) to properly calculate savings from the estimated unit usage. Savings percentages from research are measured with respect to units without quality installation verification. Percentages need to be adjusted to get the proper savings from the usage estimated by the Protocol algorithms which include the effects of these quality installation improvements.
- Further research the coincidence factor of participant units. Proper sizing and QIV can have mixed effects on peak loads at extreme temperatures. The program coincidence factor should accurately reflect the coincidence factor of CoolAdvantage units at peak temperatures.
- Replace typical furnace or boiler output capacity (91,000 Btu) with individual qualifying unit output capacity in the heating savings equation.
- Continue to update the typical replacement heating equipment AFUE values using previous methodology. Include information on market share of unit types, if possible.
- Lower baseline water heater usage in the water heating saving equation from 212 therms to 180 based on regional estimates of average water heating usage.

- The Warm- and CoolAdvantage rebate applications are designed well to collect the necessary data for program tracking and evaluation purposes. The challenge with collecting tracking data is getting the data recorded accurately in the field and then transferring it successfully into a well-designed database that captures all of the necessary program data. The Warm- and CoolAdvantage programs can improve substantially in this respect. Of particular importance is the capturing of QIV and right-sizing activity that takes place.
- QIV and right-sizing activity by contractors needs to be validated by the program.

8. Appendix – Participant Survey

Participant Survey

New Jersey's Clean Energy Program
Energy Impact Evaluation
Residential HVAC (WARMAdvantage & COOLAdvantage) Program

DRAFT
Telephone Survey

Prepared by
KEMA Inc.

0. INSTRUCTIONS

Skip patterns are indicated where necessary. If no skip is indicated then move to the next question.

The following variables are participant-specific. They are included with the sample data and are inserted into the survey instrument by the CATI program.

MEASURE ...."Furnace" or "Central Air Conditioner" or "Water Heater"
YEAR ...."2005" or "2006"
ADDRESS ....Address from tracking database
HORC ...."Heated" or "Cooled"
MEASUREFUEL .... "Electric" or "Natural gas"
BESTDATE .... Install or paid date
REBATEAMOUNT .... Rebate amount from tracking database
COOLWARM..."Cool" or "Warm"

I. INTRODUCTION SECTION

Hello, this is _______________________, and I'm calling from Braun Research on behalf of the New Jersey Clean Energy Program's [COOLWARM]Advantage Program.

[If necessary, say "New Jersey's Clean Energy Program is a statewide program that promotes energy efficiency and supports the installation of clean and renewable sources of energy."

- IF COOLWARM="Cool" THEN "The objective of the COOLAdvantage Program is to improve the energy efficiency of new electric central air conditioners and heat pumps."
- ELSE IF COOLWARM="Warm" THEN "The objective of the WARMAdvantage Program is to promote the purchase of high efficiency natural gas home heating systems and/or water heaters."]

Program records indicate you received a rebate for a [MEASURE] in [YEAR]. I'd like to ask you some questions about your new [MEASURE]. This is not a sales or marketing call. This interview will be used to help the program improve the services it provides to New Jersey households like yours. The interview should only take about 20 minutes and your responses will be kept entirely confidential.

SC. PARTICIPANT SCREENING SECTION

SC1 First, I want to make sure that I reached you at [ADDRESS]. Is this your correct address?

- (Yes) 1
- (No) (THANK AND TERMINATE).. 2
- (Don't know) (THANK AND TERMINATE) 999
- (Refused) (THANK AND TERMINATE).. 888

SC2 Is this address your home, a place of business, or both?

- (Home).. 1
- (Place of business) (THANK AND TERMINATE).. 2
- (Both) 3

F. FURNACE SECTION

[If [MEASURE]=Furnace]

F1 According to our records, you received a rebate for the installation of a furnace at this address. Is this correct?

(Yes) 1
(No Furnace installed) (THANK AND TERMINATE) 2
(No, not at this address) (THANK AND TERMINATE) 3
(Don't know) (OTHER MORE KNOWLEDGEABLE PERSON?) 999
(Refused) (THANK AND TERMINATE) 888

F2 Was the furnace installed on or shortly before [BESTDATE]?

(Yes) 1
(No) (Specify approximate Date) 2
(Don't know) 999
(Refused) (THANK AND TERMINATE) 888

F3 Is the furnace still installed and working?

(Yes) (SKIP TO F5) 1
(No) [Explain:____________________] 2
(Don't know) (SKIP TO F5) 999
(Refused) (SKIP TO F5) 888

F4 When was it removed or stopped working? [PROMPT IF NECESSARY FOR MONTH AND YEAR]

Record Month and Year (SKIP TO F6) .... __________
(Don't know) (SKIP TO F6) 999
(Refused) (SKIP TO F6) 888

F5 Is the furnace working properly?

(Yes) 1
(No) [Explain:____________________] 2
(Don't know) 999
(Refused) 888

F6 Are you satisfied with the performance of the furnace that you installed?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

F7 Do you have any concerns with the new furnace such that you would consider replacing it in the next 10 years?

(Yes) 1
(No) [Explain:____________________].. 2
(Don't know).. 999
(Refused) 888

F8 Did the rebated furnace you purchased replace another furnace or other heating system?

(Yes) 1
(No) (SKIP TO F16).. 2
(Don't know).. 999
(Refused) 888

F9 What was the heating fuel for the system you replaced?

Natural Gas.. 1
Oil (SKIP TO F12) 2
Electric (SKIP TO F12) 3
Propane (SKIP TO F12) 4
LPG (SKIP TO F12).. 5
Other (Specify) ______________________________ (SKIP TO F12) 6
(Don't know).. 999
(Refused) 888

F10 Was the old system working when it was replaced?

Working (SKIP TO F12).. 1
Working but not working well (SKIP TO F12)... 2
Not working.. 3
(Don't know) (SKIP TO F12)... 999
(Refused) (SKIP TO F12) 888

F11 When did the old system stop working?

Record Month and Year .... __________
(Don't know).. 999
(Refused) 888

F12 Does the new furnace heat the same amount of space as the previous system?

(Yes) 1
(No) (SKIP TO F14).. 2
(Don't know) (SKIP TO F15)... 999
(Refused) (SKIP TO F15) 888

F13 Was new ductwork being installed?

(Yes) (SKIP TO F15) 1
(No) (SKIP TO F15) 2
(Don't know) (SKIP TO F15) 999
(Refused) (SKIP TO F15) 888

F14 Does it heat more or less living space?

(More) 1
(Less) 2
(Don't know) 999
(Refused) 888

F15 What was the efficiency of the old unit, the one you replaced?

Record Efficiency (SKIP TO F17) .... ___________
(Don't know) 999
(Refused) 888

F16 What type of space does the new furnace serve? Does it serve…[READ RESPONSES]

A new addition 1
Existing space that was not heated at all, or 2
Existing space that was inadequately heated 3
(Other, Specify__________________________________) 4
(Don't know) 999
(Refused) 888

F17 Is the rebated furnace your primary heating system?

(Yes) (SKIP TO F19) 1
(No) 2
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1) 888

F18 What is the fuel for the primary system?

Natural Gas (SKIP TO H1) 1
Oil (SKIP TO H1) 2
Electric (SKIP TO H1) 3
Propane (SKIP TO H1) 4
LPG (SKIP TO H1) 5
Other (Specify) ______________________________ (SKIP TO H1) 6
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1) 888

F19 Do you have a secondary heating system?

(Yes) 1
(No) (SKIP TO H1) 2
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1)... 888

F20 What is the fuel of the secondary system?

Natural Gas.. 1
Oil (SKIP TO H1) 2
Electric (SKIP TO H1).. 3
Propane (SKIP TO H1).. 4
LPG (SKIP TO H1) 5
Other (Specify) ______________________________ (SKIP TO H1)........................ 6
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1)... 888

F21 Was the secondary system added or replaced in the last five years?

(Replaced) 1
(Added) (SKIP TO H1).. 2
No/neither replaced nor added (SKIP TO H1)... 3
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1)... 888

F22 Was the system that it replaced also natural gas?

(Yes) (SKIP TO H1).. 1
(No).. 2
(Don't know)... 999
(Refused) 888

F23 Approximately what month and year did that change occur?

Record Month and Year .... __________
(Don't know)... 999
(Refused) 888

WATER HEATER SECTION

[If [MEASURE]=Water Heater]

WH1 According to our records, you received a rebate for the installation of a water heater at this address. Is this correct?

(Yes) 1
(No water heater installed) (THANK AND TERMINATE) 2
(No, not at this address) (THANK AND TERMINATE) 3
(Don't know) (OTHER MORE KNOWLEDGEABLE PERSON?) 999
(Refused) (THANK AND TERMINATE) 888

WH2 Was the water heater installed on or shortly before [BESTDATE]?

(Yes) 1
(No) (Specify approximate Date) 2
(Don't know) 999
(Refused) (THANK AND TERMINATE) 888

WH3 Is the water heater still installed and working?

(Yes) (SKIP TO WH5) 1
(No) 2
(Don't know) (SKIP TO WH5) 999
(Refused) (SKIP TO WH5) 888

WH4 When was it removed or stopped working? [PROMPT IF NECESSARY FOR MONTH AND YEAR]

Record Month and Year (SKIP TO WH6).. __________
(Don't know) (SKIP TO WH6) 999
(Refused) (SKIP TO WH6) 888

WH5 Is the water heater working properly?

(Yes) 1
(No) [Explain:______________________] 2
(Don't know) 999
(Refused) 888

WH6 Are you satisfied with the performance of the water heater that you installed?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

WH7 Do you have any concerns with the new water heater such that you would consider replacing it in the next 10 years?

(Yes) 1
(No) [Explain:____________________] 2
(Don't know) 999
(Refused) 888

WH8 Did the rebated water heater you purchased replace another water heater?

(Yes) 1
(No) (SKIP TO WH 15) 2
(Don't know) 999
(Refused) 888

WH9 What was the heating fuel for the system you replaced?

Natural Gas 1
Oil (SKIP TO WH12) 2
Electric (SKIP TO WH12) 3
Propane (SKIP TO WH12) 4
LPG (SKIP TO WH12) 5
Other (Specify) ______________________________ (SKIP TO WH12) 6
(Don't know) 999
(Refused) 888

WH10 Was the old system operational when it was replaced?

Working (SKIP TO WH12) 1
Working but not working well (SKIP TO WH12) 2
Not working 3
(Don't know) (SKIP TO WH12) 999
(Refused) (SKIP TO WH12) 888

WH11 When did the old system stop working?

Record Month and Year .... __________
(Don't know) 999
(Refused) 888

WH12 Is the new water heater the same size as the previous system?

(Yes) (SKIP TO WH14) 1
(No) 2
(Don't know) (SKIP TO WH15) 999
(Refused) (SKIP TO WH15) 888

WH13 Is it bigger or smaller?

(Bigger) 1
(smaller) 2
(Don't know) 999
(Refused) 888

WH14 What was the efficiency of the old unit, the one you replaced?

Record Efficiency (SKIP TO H1) .... ___________
(Don't know) (SKIP TO H1) 999
(Refused) (SKIP TO H1) 888

WH15 So the rebated water heater is providing additional hot water beyond what the existing water heater at the time provided?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

A. CENTRAL AIR CONDITIONER SECTION

[If [MEASURE]=Central Air Conditioner]

A1 According to our records, you received a rebate for the installation of a Central Air Conditioner at this address. Is this correct?

(Yes) 1
(No Air Conditioner installed) (THANK AND TERMINATE) 2
(No, not at this address) (THANK AND TERMINATE) 3
(Don't know) (OTHER MORE KNOWLEDGEABLE PERSON?) 999
(Refused) (THANK AND TERMINATE) 888

A2 Was the Central Air Conditioner installed on or shortly before [BESTDATE]?

(Yes) 1
(No) (Specify approximate Date) 2
(Don't know) 999
(Refused) (THANK AND TERMINATE) 888

A3 Is the Central Air Conditioner still installed and working?

(Yes) (SKIP TO A5) 1
(No) [Explain:____________________] 2
(Don't know) (SKIP TO A5) 999
(Refused) (SKIP TO A5) 888

A4 When did it stop working? [PROMPT IF NECESSARY FOR MONTH AND YEAR]

Record Month and Year (SKIP TO A6) .... __________
(Don't know) (SKIP TO A6) 999
(Refused) (SKIP TO A6) 888

A5 Is the Central Air Conditioner working properly?

(Yes) 1
(No) [Explain:____________________] 2
(Don't know) 999
(Refused) 888

A6 Are you satisfied with the performance of the Central Air Conditioner that you installed?

(Yes) 1
(No) [Explain:____________________] 2
(Don't know) 999
(Refused) 888

A7 Do you have any concerns with the new Central Air Conditioner such that you would consider replacing it in the next 10 years?

(Yes) 1
(No) [Explain:____________________].. 2
(Don't know).. 999
(Refused).. 888

A8 Did the rebated Central Air Conditioner you purchased replace another Central Air Conditioner?

(Yes) 1
(No) (SKIP TO A19).. 2
(Don't know).. 999
(Refused).. 888

A9 Was the old Central Air Conditioner working when it was replaced?

Working (SKIP TO A11) 1
Working but not working well (SKIP TO A11).. 2
Not working.. 3
(Don't know) (SKIP TO A11) 999
(Refused) (SKIP TO A11).. 888

A10 When did the old system stop working?

Record Month and Year .... ___________
(Don't know).. 999
(Refused).. 888

A11 Does the new Central Air Conditioner cool the same amount of space as the previous system?

(Yes) 1
(No) (SKIP TO A15).. 2
(Don't know).. 999
(Refused).. 888

A12 Did you consider increasing or decreasing the size of the new Central Air Conditioner compared to the old one?

(Yes, Increasing) 1
(Yes, Decreasing).. 2
(No) (SKIP TO A14).. 3
(Don't know) (SKIP TO A14) 999
(Refused) (SKIP TO A14).. 888

A13 Explain [RECORD VERBATIM] (SKIPTO A16)

A14 Was new ductwork being installed?

(Yes) (SKIP TO A16) 1
(No) (SKIP TO A16) 2
(Don't know) (SKIP TO A16) 999
(Refused) (SKIP TO A16) 888

A15 Does it cool more or less space?

(More) 1
(Less) 2
(Don't know) 999
(Refused) 888

A16 What was the efficiency or SEER [IF NECESSARY "*seasonal energy efficiency ratio* is an efficiency rating for air conditioners"] of the old unit, the one you replaced?

Record Efficiency .... __________
(Don't know) 999
(Refused) 888

A17 With your previous Central Air Conditioner did you cool your house…

Every day 1
Most days 2
About half the time 3
Only on the hottest days 4
Never 5
(Don't know) 999
(Refused) 888

A18 Do you use your new Central Air Conditioner the same way?

(Yes) (SKIP TO A20) 1
(No) 2
(Don't know) (SKIP TO A20) 999
(Refused) (SKIP TO A20) 888

A19 With your new Central Air Conditioner do you cool your house…

Every day....1
Most days....2
About half the time....3
Only on the hottest days....4
Never....5
(Don't know)....999
(Refused)....888

A20 Prior to installing the new Central Air Conditioner did you use any room air conditioners?

(Yes)....1
(No) (SKIP TO A22)....2
(Don't know) (SKIP TO A22)....999
(Refused) (SKIP TO A22)....888

A21 How many room air conditioners did you use regularly?

(One)....1
(Two)....2
(Three)....3
(More than Three)....4
(Don't know....999
(Refused)....888

A22 With the new Central Air Conditioner do you use room air conditioners?

(Yes)....1
(No) (SKIP TO H1)....2
(Don't know) (SKIP TO H1)....999
(Refused) (SKIP TO H1)....888

A23 How many room air conditioners do you still use regularly?

(One)....1
(Two)....2
(Three)....3
(More than Three)....4
(Don't know)....999
(Refused)....888

H. HOME SECTION

"Next, I'd like to ask some questions about your house where the [MEASURE] was installed."

H1 What is the square footage of the [HORC] portion of your house?

- Record number of square feet (SKIP TO QUESTION H3) .... __________
- (Don't know)..999
- (Refused)..888

H2 What is your best estimate of this area? Would you say it is…(READ LIST)

- Less than 600 square feet..1
- 600 to 999 square feet..2
- 1,000 to 1,599 square feet..3
- 1,600 to 1,999 square feet..4
- 2,000 to 2,399 square feet..5
- 2,400 to 2,999 square feet..6
- 3,000 or more square feet..7
- (Don't know)..999
- (Refused)..888

H3 Currently, how many rooms are there in your home, not counting bathrooms, halls, unheated basement areas or garages?

- Record Number of Rooms.. __________
- (Don't know)..999
- (Refused)..888

H4 Is your home a… [READ RESPONSES]

- Single-family Detached Home (SKIP TO QUESTION H6).......................................1
- Mobile Home (SKIP TO QUESTION H6)..2
- Duplex/Triplex/4-plex..3
- In a multifamily building with more than 4 units...4
- (Don't know)..999
- (Refused)..888

H5 Does your [HORC] system serve only this home?

- (Yes)..1
- (No) (THANK AND TERMINATE)..2
- (Don't know)..999
- (Refused)..888

H6 Approximately what year was the house built?

Record Year..___________
(Don't know)...999
(Refused)...888

H7 How many years have you lived at this address?

Record Number of Years..___________
(Don't know)...999
(Refused)...888

H8 Do you rent or own?

(Rent)...1
(Own) (SKIP TO C1)..2
(Don't know) (SKIP TO C1)...999
(Refused) (SKIP TO C1)..888

H9 Do you pay the gas bill?

(Yes)..1
(No)..2
(Don't know)...999
(Refused)...888

C. CHANGES SECTION

"We would like to account for changes in household [MEASUREFUEL] usage OTHER than the installation of the new energy efficient [MEASURE]."

C1 In the last five years, have you replaced any windows or installed insulation?

(Yes) 1
(No) (SKIP TO C4) 2
(Don't know) (SKIP TO C4) 999
(Refused) (SKIP TO C4).. 888

C2 Do you think you lowered the energy usage in your house with the window or insulation work?

(Yes) 1
(No) (SKIP TO C4) 2
(Don't know) (SKIP TO C4) 999
(Refused) (SKIP TO C4).. 888

C3 Approximately what month and year did that change occur?

Record Month and Year .... __________
(Don't know).. 999
(Refused) 888

C4 Has there been a change in the number of people living in your home?

(Yes) 1
(No) (SKIP TO C8) 2
(Don't know) (SKIP TO C8) 999
(Refused) (SKIP TO C8).. 888

C5 Did the number of people increase or decrease?

(Increase).. 1
(Decrease) 2
(Don't know).. 999
(Refused) 888

C6 By how many people?

Number of People.. __________
(Don't know).. 999
(Refused) 888

C7 Approximately what month and year did that change first occur? [IF MULTIPLE CHANGES, NOTE DATE OF FIRST CHANGE MENTIONED.]

Record Month and Year .... __________
(Don't know)...999
(Refused)..888

C8 Have you changed the temperature setting at which your house is generally [HORC] by more than 3 degrees?

(Yes)...1
(No) (SKIP TO SECTION AP)...2
(Don't know) (SKIP TO SECTION AP)..999
(Refused) (SKIP TO SECTION AP)..888

C9 Is your new temperature warmer or cooler than before?

(Cooler)...1
(Warmer)...2
(Don't know)..999
(Refused)...888

C10 Approximately what month and year did that change occur?

Record Month and Year .... __________
(Don't know)...999
(Refused)..888

AP. APPLIANCES

Another way [MEASUREFUEL] usage can increase or decrease in a household is through changes with other [MEASUREFUEL] appliances. These changes could include the addition or removal of an appliance or the replacement of an old appliance with a new one.

[If [MEASURE] = Furnace]

AP1 Have you made any changes in the last five years related to other major gas appliances such as gas water heat, gas cooking equipment or gas dryer?

- Yes.......................................1
- No (SKIP TO FR1)..........................2
- (Don't know) (SKIP TO FR1)................999
- (Refused) (SKIP TO FR1) 888

[If [MEASURE] = Central Air Conditioner]

AP1 Have you made any changes in the last five years related to other major electric appliances such as an electric furnace, electric water heat, refrigerator or freezer, or washer or dryer?

- Yes.......................................1
- No (SKIP FR1).............................2
- (Don't know) (SKIP TO FR1)................999
- (Refused) (SKIP TO FR1) 888

[If [MEASURE] = Water heater]

AP1 Have you made any changes in the last five years related to other major gas appliances such as a gas furnace, gas cooking equipment or gas dryer?

- Yes.......................................1
- No (SKIP TO FR1)..........................2
- (Don't know) (SKIP TO FR1)................999
- (Refused) (SKIP TO FR1) 888

AP2 What appliance was the biggest change made to?…

([MEASUREFUEL] Space Heat) 1
([MEASUREFUEL] Water Heat) 2
([MEASUREFUEL] Clothes Dryer) 3
([MEASUREFUEL] Cooking equipment) 4
(Refrigerator/Freezer) 5
(Clothes washer) 6
Other [Explain:____________________] 7
(Don’t know) (SKIP TO FR1) 999
(Refused) (SKIP TO FR1) 888

AP3 As a result of that change, do you think your [MEASUREFUEL] usage increased, decreased or remained the same?

Increased 1
Decreased 2
Stayed the same 3
(Don’t know) (SKIP TO FR1) 999
(Refused) (SKIP TO FR1) 888

AP4 Approximately what month and year did that change occur?

Record Month and Year .... __________
(Don’t know) (SKIP TO FR1) 999
(Refused) (SKIP TO FR1) 888

FR. FREE RIDERSHIP

"Now, I'd like to ask a few questions about your decision to install your [MEASURE]."

FR1 How did you first hear about the rebate program?

- (Contractor or salesperson) 1
- (Bill insert from utility) 2
- (Utility Website) 3
- (Newspaper/magazine/radio/TV ads) 4
- (Friend/acquaintance) 5
- (Other, Specify) ______________________ 6
- (Don't know) 999
- (Refused) 888

FR2 Prior to approaching your contractor to purchase the new [MEASURE], were you aware that some models were significantly more energy efficient than others?

- (Yes) 1
- (No) (SKIP TO SECTION SP) 2
- (Don't know) (SKIP TO SECTION SP) 999
- (Refused) (SKIP TO SECTION SP) 888

FR3 You received a [REBATEAMOUNT] rebate on the purchase of your energy-efficient [MEASURE]. On a 10-point scale where 1 means "not at all likely" and 10 means "very likely", how likely is it that you would have purchased a [MEASURE] with the same high efficiency rating if you had not been offered the rebate?

- Record number .... __________
- (IF NUMBER IS <10, PROCEED TO FR4. OTHERWISE SKIP TO SECTION SO)
- (Don't know) (SKIP TO SECTION SP) 999
- (Refused) (SKIP TO SECTION SP) 888

FR4 Using the same 10-point scale where 1 means "not at all likely" and 10 means "very likely", how likely is it that you would have postponed the purchase of the energy-efficient system for more than a year?

- Record number .... __________
- (Don't know) 999
- (Refused) 888

SO. SPILLOVER

SO1 As a result of installing the energy efficient [MEASURE], do you have more confidence about the energy savings that can result from installing energy-efficient technologies?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

SO2 Are you more confident about the reliability of energy-efficient technologies?

(Yes) 1
(No) 2
(Don't know) 999
(Refused)) 888

SO3 Did making these improvements introduce you to new installation contractors or equipment dealers?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

SO4 As a result of your participation in this program, are you more aware of your household energy usage or costs?

(Yes) 1
(No) 2
(Don't know) 999
(Refused) 888

SO5 Since purchasing the rebated [MEASURE] have you made additional energy efficiency improvements at your house WITHOUT a rebate from New Jersey's Clean Energy Program or your utility?

(Yes) 1
(No) (SKIP TO SO8) 2
(Don't know) (SKIP TO SO8) 999
(Refused) (SKIP TO SO8) 888

SO6 Thinking about the biggest of these improvements, how influential was the experience of installing the [MEASURE] in motivating this additional energy efficiency improvement? On a scale of 1 to 10 where 1 means “Not at all Influential” and 10 means “Very Influential.”

Record number .... __________
(Don’t Know) 999
(Refused) 888

SO7 What improvements did you make?

Explain________________________

SO8 Are you aware of energy efficiency improvements you could make but haven’t yet?

(Yes) 1
(No) (SKIP TO P1) 2
(Don’t know) (SKIP TO P1) 999
(Refused) (SKIP TO P1) 888

SO9 Again, on a scale of 1 to 10 where 1 means “not at all likely” and 10 means “very likely”, how likely are you to make at least one of these energy efficiency improvements in the next 3 years WITHOUT a rebate.

Record number .... __________
(Don’t know) (SKIP TO P1) 999
(Refused) (SKIP TO P1) 888

SO10 Thinking about this future improvement you might do, how influential do you think this experience of installing the [MEASURE] will be in motivating this additional energy efficiency improvement? On a scale of 1 to 10 where 1 means “Not Influential” and 10 means “Very Influential.”

Record number .... __________
(Don’t Know) 999
(Refused) 888

P. OTHER PROGRAM PARTICIPATION

P1 In addition to [WARMCOOL]Advantage, are you familiar with any other New Jersey Clean Energy Programs?

(Yes) 1
(No) (SKIP TO D1) 2
(Don't know) (SKIP TO D1) 999
(Refused) (SKIP TO D1).. 888

P2 Which programs?

[RECORD VERBATIM RESPONSE]

P3 Have you participated in any of these programs?

(Yes) 1
(No) (SKIP TO D1) 2
(Don't know) (SKIP TO D1) 999
(Refused) (SKIP TO D1).. 888

P4 Which programs?

[RECORD VERBATIM RESPONSE]

D. DEMOGRAPHICS SECTION

These final questions are for comparison purposes only.

D1 Including yourself, how many people live in your home at least 6 months of the year?

Number of persons .... __________

D2 How many of these persons are children under age 18?

Number of persons .... __________

D3 How many of these persons are over 65?

Number of persons ....__________

D4 What is the highest level of education you have completed?

Eighth grade or less...1
Some high school 2
Graduated high school 3
Some college or technical school..4
Graduated college or technical school 5
Post graduate work...6
(Refused) 888

D5 Which of the following categories best describes your total household income during [REBATE YEAR]?

under $50,000 5
$50,000 to under $75,000 6
$75,000 to under $100,000 7
Over $100,000...8
(Refused) 888

D6 (Record gender of respondent.)

(Male)..1
(Female) 2

“Those are all of my questions. Thank you very much for taking the time to participate in this study.”