EmPOWER Maryland

FINAL Evaluation Report

Evaluation Year 4 (June 1, 2012 – May 31, 2013)

Residential HVAC Program

Presented to

Baltimore Gas & Electric
Potomac Electric Power Company
Delmarva Power & Light
Southern Maryland Electric Cooperative
Potomac Edison

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Section 1. Executive Summary

EmPOWER Maryland's Residential Heating, Ventilation, and Air Conditioning (HVAC) program seeks to increase the purchase and installation of high-efficiency heating and cooling equipment and service measures in homes across the five EmPOWER utility territories: Baltimore Gas & Electric (BGE), Delmarva Power & Light (DPL), Potomac Electric Power Company (Pepco), Potomac Edison (PE), and Southern Maryland Electric Cooperative (SMECO). The utilities provide consumer marketing and support, and they work with networks of participating contractors who are the primary drivers of program activity.

This report presents the results of an impact evaluation of HVAC program activity between June 1, 2012, and May 31, 2013, which is referred to as Evaluation Year 4 (EY4) in this report.[1] During this period, the impact evaluation had these main research objectives:

- Provide evaluated gross peak demand and annual energy savings (including verification of measure installations) for the population of measures installed through the program.
- Provide estimates of net energy impacts.
- Estimate uncertainty around evaluated savings.
- Provide recommendations for upcoming program years with respect to promoted measures, savings calculations, and data collection and reporting.

Previous EmPOWER evaluation reports presented the savings impacts from earlier implementation cycles. The evaluation team combined some of the results of this previous research with EY4 results to increase the accuracy and precision of EY4 results. Section E.5.3 discusses the combining of results.

In 2011, the evaluation team and the EmPOWER utilities agreed to shift evaluation cycles from program years (which follow the calendar year) to the PJM cycle (which runs June 1-May 31). A summary of evaluation year timeframes is provided in Table 1.

[1] While program (implementation) cycles operate in calendar years, the evaluation period shifted in 2012 to align with PJM's installation year.

Table 1. Evaluation Year Timeframes

Evaluation Year	Timeframe
EY1	January 1, 2010 - December 31, 2010
EY2	January 1, 2011 - September 30, 2011
EY3	October 1, 2011 - May 31, 2012
EY4	June 1, 2012 – May 31, 2013

Consistent with the approach used in previous years, the evaluation team plans to deliver a supplemental evaluation report on calendar year 2013 program impacts in April 2014.

Table 2 lists the impact evaluation activities conducted for the EmPOWER Residential HVAC programs since EY1. An "X" designates activities performed for all program measures; other activities are called out specifically.

Table 2. Impact Evaluation Activities by Year

Utility	Activity	2010 (EY1)	2011 (EY2)	2012 (EY3)	2013 (EY4)
BGE	Engineering review	X	X	X	X
	Phone verification	X	X	X	All equipment measures
	NTG	X	X	X	X
	On-site Verification	CACs & ASHPs	---	---	---
	Metering	CACs & ASHPs	---	---	---
Pepco & DPL	Engineering Review	X	X	X	X
	Phone Verification	X	X	X	All equipment measures
	NTG	X	X	X	X
	On-site Verification	---	---	CACs & ASHPs	---
	Metering	---	---	CACs & ASHPs	ASHPs
PE	Engineering Review	X	X	X	X

Utility	Activity	2010 (EY1)	2011 (EY2)	2012 (EY3)	2013 (EY4)
	Phone Verification	X	X	X	All equipment measures
	NTG	X	X	X	X
	On-site Verification	---	---	CACs & ASHPs	---
	Metering	---	---	CACs & ASHPs	ASHPs
SMECO	Engineering Review	X	X	X	X
	Phone Verification	X	X	X	All equipment measures
	NTG	X	X	X	X
	On-site Verification	---	---	CACs & ASHPs	---
	Metering	---	---	CACs & ASHPs	ASHPs

Note: CAC = central air conditioner, ASHP = air-source heat pump

Table 3 summarizes the Residential HVAC programs' EY4 PJM coincident peak demand savings. The table shows each utility's tracked and evaluated gross savings and the gross realized savings ratio for EY4. The combined metering in EY1 and EY3 indicated that demand savings for CACs and ASHPs were about 20% higher than what was tracked by utilities. This resulted in a high gross realized saving ratio for all utilities. The evaluation team expects to see a realized savings ratio closer to 1.00 in the next program year as utilities continue to adopt the recommended evaluated savings values.

Table 3. PJM Coincident Peak Demand Savings Summary (kW)*

Utility	Ex Ante Program Tracked Savings June 1, 2012 – May 31, 2013	Gross Realized Savings Ratio	Evaluated Gross Savings
BGE	2,557	1.15	2,936
Pepco	988	1.15	1,132
DPL	120	1.24	149
PE	334	1.11	371
SMECO	282	1.43	403
Statewide Total	**4,280**	**1.17**	**4,991**

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis
Note: Values reported in the table are rounded.
* Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM savings.

Table 4 summarizes the Residential HVAC programs' utility coincident peak demand savings, showing each utility's tracked and evaluated gross savings for EY4 as well as the gross realized savings ratio, the net-to-gross (NTG) ratio[2], and the evaluated net savings. On average, the gross realized demand savings ratio is closer to 1.0 than it was in EY3, as utilities adopt the recommended savings calculation methodologies. PE's gross realized savings ratio is 1.8 because a detailed engineering review found that the utility underestimated its tune-up savings. Because those savings make up approximately 75% of PE's reported HVAC measures, the underestimation had a large impact on the gross realized savings ratio.

[2] The freeridership rates were relatively high compared to other utility HVAC programs throughout the country. For additional information about what the rates were high, please see the HVAC process memorandum.

Table 4. Utility Coincident Peak Demand Savings Summary (kW)

Utility	Ex Ante Program Tracked Savings June 1, 2012 – May 31, 2013	Gross Realized Savings Ratio	Evaluated Gross Savings	NTG	Evaluated Net Savings
BGE	3,161	0.94	2,932	0.39	1,143
Pepco	1,299	0.84	1,092	0.40	437
DPL	205	0.87	179	0.40	72
PE	400	1.80	721	0.36	260
SMECO	414	1.02	422	0.37	156
Statewide Total	**5,479**	**0.98**	**5,347**	**0.39**	**2,068**

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

Table 5 summarizes the Residential HVAC programs' energy savings for each of the EmPOWER utilities, showing tracked and evaluated gross savings for EY4 and the gross realized savings ratio, NTG ratio, and evaluated net savings. On average, the gross realized energy savings ratio is 0.84. Utilities continue to adopt the savings calculation methodologies recommended by the evaluation team bringing the gross realized energy savings ratio closer to 1. Ground-source heat pump (GSHP) evaluated savings changed this year, which effectively decreased the realized savings ratio. PE's gross realized savings ratio was 1.8 because they underestimated tune-up savings, which comprise the majority of their total reported measures.

Table 5. Energy Savings Summary (MWh)

Utility	Ex Ante Program Tracked Savings June 1, 2012 – May 31, 2013	Gross Realized Savings Ratio	Evaluated Gross Savings	NTG	Evaluated Net Savings
BGE	8,129	0.78	6,373	0.39	2,486
Pepco	2,020	0.80	1,614	0.40	646
DPL	550	0.77	424	0.40	170
PE	1,097	1.47	1,609	0.36	579
SMECO	1,303	0.78	1,022	0.37	378
Statewide Total	**13,099**	**0.84**	**11,041**	**0.39**	**4,258**

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis
Note: Values reported in table are rounded.

Section 2. Gross Impact Evaluation

This section describes the gross program savings impacts for the EmPOWER HVAC programs for EY4.

2.1 Overview of Methodology

Table 6 lists the Residential HVAC gross impact evaluation activities conducted in EY4 for each utility.

Table 6. Overview of EY4 Gross Impact Evaluation Activities for Residential HVAC

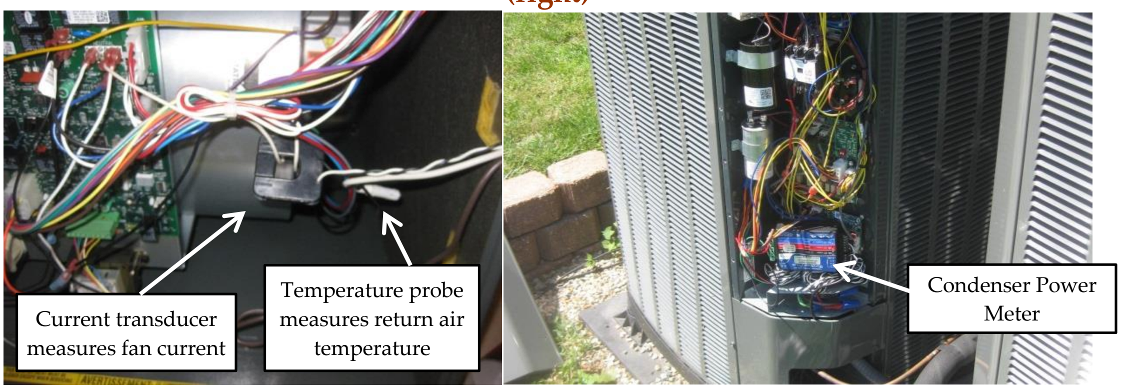
Activity	BGE	Pepco	DPL	PE	SMECO
Engineering review	X	X	X	X	X
Phone verification	X	X	X	X	X
ASHP metering		X		X	X

The following list provides additional details on each evaluation activity.

- **Engineering Review (All utilities)**
  - The evaluation team conducted an engineering review of savings recorded in the tracking systems across all measures, for all utilities.
  - The evaluation team provided a more in-depth analysis of tune-ups than in past years, estimating savings based on detailed data the utilities collected.
  - Appendix E (page 32) provides more details about the analysis.
- **Phone Verification (All utilities)**
  - The evaluation team used a phone survey with 101 customers (25 customers each from BGE, SMECO, and PE, and 13 each from Pepco and DPL).
  - The survey included questions to confirm customers installed equipment and received a utility rebate, as well as batteries to determine self-report NTG and customer satisfaction with the program.
  - Appendix D (page 29) provides more details about the survey.
- **ASHP Metering (Pepco, DPL, PE, SMECO)**
  - The evaluation team analyzed data from ASHP meters that were installed in Pepco, DPL, SMECO, and PE territories between summer of 2012 and spring of 2013. To increase precision, the team combined these data with results from a similar ASHP metering study the team conducted in 2010 in BGE's territory.

- The measurement and verification activities undertaken were compliant with PJM Manual 18B. Section E.5 (page 41) provides more details about the metering study.
- Figure 1 shows the meters that recorded fan current, return air temperature (RAT), and condenser power at two-minute intervals.

Figure 1. Metering Fan Current and Return Air Temperature (left) and Condenser Power (right)



The appendices provide details on the evaluation approach and findings. Appendices include the following:

» Descriptions of the residential HVAC programs by utility (Appendix A, page 22)
» Gross impact measurement and verification methodology (Appendix B, page 27)
» Relevant codes and standards as well as assumptions regarding baseline equipment used for calculating savings (Appendix C, page on page 28)
» Detailed gross impact evaluation verification activities (Appendix D, page 29)
» Detailed gross impact evaluation measurement and metering activities (Appendix E, page 32)
» Statistical significance of gross impacts (Appendix F, page 62)

2.2 *Findings*

The evaluation team determined the evaluated gross kWh, utility peak kW, and PJM peak kW savings for each utility by applying the gross realized savings ratio for each utility to the ex ante tracked savings. The team used results from the following activities to determine evaluated savings.

» ASHPs and CACs: Results from metering studies in EY1 and EY3-EY4, which adjusted the full load hour values used in the TRM algorithms (see Table 30).

- Tune-ups: Engineering review of contractor invoices and/or tune-up worksheets with metered energy consumption from metering studies in EY1 and EY3-EY4.
- Duct Sealing: Engineering review of reported savings.
- Ductless HPs and ACs: Metered energy consumption of central ACs and HPs.
- ECM motors: Engineering review or reported savings.

If tracking data for system size and efficiency information was available, the evaluation team used that information to estimate savings for each measure reported. The team adjusted metered energy consumption and savings for each utility using a ratio of heating and cooling degree days metered to the representative degree days in each utility. [3]

The following subsections show the evaluated gross savings results for each utility and the combined statewide programs.

2.2.1 Statewide Findings

Table 7 provides a summary of statewide EmPOWER savings. The utility peak demand evaluated savings is higher than the reported savings mainly because the evaluation found the reported ASHP and tune-up demand savings to be low for all utilities.

Section E.6 provides a detailed explanation of realized savings ratios by measure type for each utility.

Table 7. Statewide 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	4,280	4,991	1.17
Utility Coincident Peak Demand Savings (kW)	5,479	5,347	0.98
Annual Energy Savings (MWh)	**13,099**	**11,041**	**0.84**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

[3] When tracking database reported zip codes by measure, utility-specific HDD and CDD were generated by averaging degree days mapped to zip codes for each measure reported.

Note: Values reported in the table are rounded.

2.2.2 BGE Findings

Table 8 shows BGE's HVAC program ex ante and evaluated gross energy and demand impacts for EY4. The major differences in reported and evaluated savings are due to updated ASHP metered results, a change in the baseline assumption for the GSHP measure, and use of an equivalent full load hours (EFLH) value to estimate savings for CACs that is different from the EFLH value of 715 hours recommended by Itron.[4] Measure-level summaries and details are provided in Section E.6.1.

Table 8. BGE 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	2,557	2,936	1.15
Utility Coincident Peak Demand Savings (kW)	3,161	2,932	0.93
Annual Energy Savings (MWh)	**8,129**	**6,373**	**0.78**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.
** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.
Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis
Note: Values reported in the table are rounded.

2.2.3 Pepco Findings

Table 9 reports on Pepco's HVAC program ex ante and evaluated gross energy and demand impacts for EY4. The major differences in reported and evaluated PJM demand savings are due to updated metering results from the EY3-EY4 CAC and ASHP metering study. Although ex post utility demand and energy savings increased for ASHPs and CACs, an engineering review found tune-up savings were less than reported savings resulting in utility energy and demand realized savings ratios were less than 1.0. Measure-level summaries and details are provided in Section E.6.2.

[4] Itron estimated 715 EFLH from meter data in PY2 but this estimate was not weather-normalized: Itron, Inc. *Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs*. April 2011. Page 4-4

Table 9. Pepco 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	988	1,132	1.15
Utility Coincident Peak Demand Savings (kW)	1,299	1,092	0.84
Annual Energy Savings (MWh)	**2,020**	**1,614**	**0.80**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.
** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.
Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis
Note: Values reported in the table are rounded.

2.2.4 DPL Findings

Table 10 reports on DPL's HVAC program ex ante and evaluated gross energy and demand impacts for EY4. ASHPs account for a large portion of savings and the ex ante savings reported for heat pumps was about 15% less than ex post savings. GSHP savings were less than reported because the evaluation assumed a GSHP rather than ASHP represents the baseline efficiency for this measure. The differences in ASHP and GSHP ex post and ex ante utility demand savings result in gross realized savings ratios that are slightly under 80%. Measure-level summaries and details are provided in Section E.6.3.

Table 10. DPL 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	120	149	1.24
Utility Coincident Peak Demand Savings (kW)	205	179	0.87
Annual Energy Savings (MWh)	**550**	**424**	**0.77**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

2.2.5 PE Findings

Table 11 reports on PE's HVAC program ex ante and evaluated gross energy and demand impacts for EY4. PE's high tune-up participation drives the gross realized savings ratios for energy and demand. The evaluation engineering review found the reported tune-up savings were low compared to the evaluated savings estimates. Reported tune-up deemed savings were only 32 kWh per tune-up (less than 2% of energy consumption), much less than the evaluation team determined through their engineering review of reported tune-up data.[5] Measure-level summaries and details are provided in Section E.6.4.

[5] Note the evaluated savings were based on limited information provided by PE's submission of a random sample of tune-up invoices and worksheets. PE should consider the evaluation team's recommendation (Section 4.1.2) and understand savings may change in EY5 as more detailed information becomes available.

Table 11. PE 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	334	371	1.11
Utility Coincident Peak Demand Savings (kW)	400	721	1.80
Annual Energy Savings (MWh)	**1,097**	**1,609**	**1.47**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

2.2.6 SMECO Findings

Table 12 reports on SMECO's HVAC program ex ante and evaluated gross energy and demand impacts for EY4. The major differences in reported and evaluated savings are due to updated ASHP metered results and use of an EFLH value to estimate savings for CACs that is different from the Itron-recommended EFLH value of 715 hours that SMECO uses. Measure-level summaries and details are provided in Section E.6.5.

Table 12. SMECO 2012-2013 Evaluation Year* Ex Ante Reported and Ex Post Evaluated Gross Annual Savings

	Ex Ante Tracked Gross Savings	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	282	403	1.43
Utility Coincident Peak Demand Savings (kW)	414	422	1.02
Annual Energy Savings (MWh)	**1,303**	**1,022**	**0.78**

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

** Utilities only bid CAC and ASHP measures into the PJM Forward Capacity Market; therefore, only savings for those measures are included in PJM Coincident Peak Demand savings.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

Section 3. Net Impact Evaluation

3.1 *Overview of Methodology*

The evaluation team used the results of a participant phone survey to estimate the NTG ratio for the EmPOWER Residential HVAC programs. In October 2013, the team surveyed 101 customers who participated in the program during EY4 (June 1, 2012, through May 31, 2013). These results were combined with 72 survey responses collected in November 2012 from customers who participated in EY3. The team designed both survey samples to achieve 10% precision with a one-tailed test at the 90% level of confidence for the statewide program. Table 13 shows the number of survey respondents by utility.

Table 13. Participant Survey Respondents by Utility

	BGE	Pepco	DPL	PE	SMECO	Total
EY4 Survey Respondents	25	13	13	25	25	101
EY3 Survey Respondents	18	14	4	18	18	72
Total	43	27	17	43	43	173

Survey respondents answered a battery of questions designed to measure freeridership and spillover. Freeriders are program participants who would have purchased the same efficient measure at the same time in the program's absence. Spillover comes from customers' decisions to invest in additional efficiency measures beyond those rebated through the program. The team adjusted the evaluated gross savings based on the measure-level freeridership and spillover results to determine the evaluated net savings, or total savings attributable to each utility's program.

To assess the rate at which EmPOWER residential customers would purchase efficient equipment in the program's absence, the evaluation team collected one year of CAC and ASHP sales data from five Maryland HVAC distributors. Using these data, the team estimated the standard efficiency levels for residential CAC and ASHP equipment typically installed in Maryland. Although the data provided important insight into the Maryland HVAC market, the evaluation team found that additional data was necessary to develop a new net baseline for the program (see Appendix G, page 66 for more details).

3.1.1 Standard Market Practice Study

Through the standard market practice study, the evaluation team obtained Q3 2012 through Q2 2013 CAC and ASHP Maryland condenser sales data from five distributors (see Appendix G, page 66, for more details). The team estimates that these data represent approximately 36% of the statewide CAC and ASHP sales.

Because an electronically commutated motor (ECM) will generally increase the seasonal energy efficiency ratio (SEER) of a CAC or ASHP one SEER level, the team used qualitative feedback from the participant and non-participant contractor focus groups (discussed in the 2013 Residential HVAC Process Evaluation Memo) to approximate the number of CACs and ASHPs installed with ECMs. Applying ECM installation estimates to the statewide distributor sales data, the team estimated that over 72% of the CAC and 63% of the ASHP sales during the 2012-2013 season were 13 SEER or below (see Section G.2.1 for details).

The team also estimated that the EmPOWER utilities' residential customers represent approximately 84% of the total residential customers in the state. By dividing the high-efficiency sales in the EmPOWER tracking data by the adjusted number of high-efficiency sales in the EmPOWER territory each year, the team estimated that the EmPOWER programs account for 82% of the high-efficiency CAC and ASHP sales in the EmPOWER utilities' territories.

Due to the low percentage of the market covered by the distributor data collected through this study and the uncertainty around qualitative ECM feedback from the focus groups, the evaluation team did not include results from the standard market practice study in the NTG analysis. However, the data allowed the team to estimate that the Residential HVAC program activity accounts for a significant portion of Maryland's high-efficiency HVAC market (see Section G.2.1 for details).

3.1.2 Participant Phone Survey

The evaluation team conducted phone surveys with participants to assess their HVAC purchasing decisions and to estimate freeridership, spillover and NTG for the program. Over a two-year period, the evaluation team surveyed 173 participating customers from the EmPOWER utilities.[6] The team designed each year's survey sample to achieve a 10% precision with a one-tailed test at the 90% level of confidence at the program level.

During the phone survey, participants answered questions designed to measure freeridership and spillover. True freeriders are program participants who would have purchased the same

[6] Pepco and DPL customers were combined for the NTG analysis because of the lower number of participants in DPL's territory and the similarity between the two programs.

efficient measure at the same time in the program's absence. Spillover comes from customers' decisions to invest in additional efficiency measures beyond those rebated through the program.[7]

The team used the 173 survey results obtained over a two year period to develop statewide freeridership estimates based off these three measure categories: (1) ASHPs, (2) CACs, and (3) Other. The team then applied the statewide measure category freeridership estimates to the measure category ex-post evaluated gross kWh savings for each specific utility to arrive at a population weighted freeridership estimate for each utility. Spillover was estimated only from the 101 survey results obtained through the EY4 survey efforts, not from the combination of EY3 and EY4 survey results. The team combined the resulting freeridership and spillover estimates for each utility to arrive at that utility's net-to-gross (NTG) ratios. The team then applied the utility NTG ratios to their evaluated gross savings to determine the evaluated net savings, or total savings attributable to the programs.

3.1.3 Findings

Table 15 through Table 19 show the NTG ratio, evaluated gross savings, and evaluated net savings for each utility's HVAC program. The evaluation team provided each utility with a program-level NTG ratio, which should be applied to all measures within the HVAC program.

For all utilities and the statewide program, the NTG ratio is low and the evaluated net savings are notably lower than the evaluated gross savings. The low NTG ratios are due to the large percentage of participants (83% overall) who were considered partial or full freeriders based on their survey responses. Although the team did not use the market study results for the NTG calculation (see Section 3.1.1 for details), the findings from that research indicate that a large portion of the high-efficiency CACs and ASHPs are purchased by program participants, which is consistent with the low NTG rates.

[7] In this study we only assessed participant spillover, or those additional energy-efficient actions taken by participants in the utility HVAC programs.

Table 14. Statewide 2012-2013 Evaluation Year* Ex Post Evaluated Net Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.39	5,347	2,068
Annual Energy Savings (MWh)	0.39	11,041	4,258

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

Source: Cadmus analysis

Note: Values reported in the table are rounded.

Table 15. BGE 2012-2013 Evaluation Year* Ex Post Evaluated Net Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.39	2,932	1,143
Annual Energy Savings (MWh)	0.39	6,373	2,486

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

Source: Cadmus analysis

Note: Values reported in the table are rounded.

Table 16. Pepco 2012-2013 Evaluation Year* Ex Post Evaluated Net Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.40	1,092	437
Annual Energy Savings (MWh)	0.40	1,614	646

* The evaluation covers the period from June 1, 2012, through May 31, 2013.

Source: Cadmus analysis

Note: Values reported in the table are rounded.

Table 17. DPL 2012-2013 Evaluation Year* Ex Post Evaluated Net Annual Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.40	179	72
Annual Energy Savings (MWh)	0.40	424	170

* The evaluation covers the period from June 1, 2012, through May 31, 2013.
Source: Cadmus analysis
Note: Values reported in the table are rounded.

Table 18. PE 2012-2013 Evaluation Year* Ex Post Evaluated Net Annual Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.36	721	260
Annual Energy Savings (MWh)	0.36	1,609	579

* The evaluation covers the period from June 1, 2012, through May 31, 2013.
Source: Cadmus analysis
Note: Values reported in the table are rounded.

Table 19. SMECO 2012-2013 Evaluation Year* Ex Post Evaluated Net Annual Savings

	Ex Post Evaluated NTG Ratio	Ex Post Evaluated Gross Savings	Ex Post Evaluated Net Savings
Utility Coincident Peak Demand Savings (kW)	0.37	422	156
Annual Energy Savings (MWh)	0.37	1,022	378

* The evaluation covers the period from June 1, 2012, through May 31, 2013.
Source: Cadmus analysis
Note: Values reported in the table are rounded.

Section 4. Recommendations

The evaluation team provides the following recommendations based on the impact evaluation's findings. In some cases, the utilities are already incorporating these recommendations into their 2012-2014 plans.

4.1 *Savings Calculation Recommendations*

4.1.1 Modified Version of TRM Algorithm (All Utilities)

All utilities should use utility-specific equivalent full load hour (EFLH) values to calculate energy savings for CACs and ASHPs. This modification of the Mid-Atlantic TRM EFLH value allows utilities to use consistent savings methodologies across the programs while accounting for climatic differences among the utilities' service territories. The EFLH values are provided in Appendix E, Table 30.

The team also recommends using the specific demand savings values (kW/ton) reported in EY3 (see Table 20) for each utility that are based on the PJM demand savings methodology.

Table 20. Evaluated Gross Demand Savings (kW/ton)

Demand Period	Measure	BGE	Pepco	DPL	SMECO	PE
PJM Coincident Demand	CAC	0.110	0.114	0.105	0.114	0.091
	ASHP	0.132	0.135	0.128	0.135	0.117
Utility Coincident Demand	CAC	0.098	0.100	0.095	0.100	0.087
	ASHP	0.119	0.122	0.117	0.122	0.108

4.1.2 Tune-Ups (All utilities)[8]

The tune-up information currently collected by utilities does not provide enough detail to confidently estimate tune-up savings. In addition to the data currently collected, utilities should require that contractors report and collect the following information for every tune-up. This qualitative information will help evaluation team better understand the savings potential of the units tuned up in each utility.

[8] Note the evaluated savings were based on limited information obtained through a random sample of tune-up invoices and worksheets. Utilities should consider the evaluation team's recommendation and understand savings may change in EY5 as more detailed information becomes available.

- Report:
  - Does the system have an existing maintenance agreement?
  - Has the customer signed up for a maintenance agreement?
- Collect:
  - Condenser condition prior to service (e.g., scale of 1-5)
    - Was it cleaned during service? Were bent fins fixed?
  - Evaporator condition prior to service (e.g., scale of 1-5)
    - Was it cleaned during service?
  - Blower assembly condition prior to service (e.g., scale of 1-5)
    - Was it cleaned during service? Were bent fins fixed?
  - Air filter condition prior to service (e.g., scale of 1-5)
  - What is the estimated remaining life of system?
  - Does contractor recommend system replacement?

If the recommended information is collected, the evaluation team will be able to review the differences in tune-up service required for HVAC systems that have existing maintenance agreements. The information could also help to explore appropriate freeridership estimates for each type of tune-up participant (those with maintenance agreements and those without agreements).

4.1.3 Duct Sealing (All utilities)

Utilities who are not collecting the following information should consider requiring this information on their application forms. This information will allow the evaluation team to accurately calculate duct sealing savings for each reported measure.

- Duct location (conditioned/unconditioned space)
- Duct leakage rate prior to service
- Heating system type (gas or electric heat pump, electric resistance heat)
- Central cooling system age

4.2 Potential Changes to Program Design and Offerings (All utilities)

The utilities should consider adding an ASHP commissioning measure in which they would commission the system to optimize operation of the ASHP and minimize use of backup electric heat. As part of this measure, utilities should consider additional outreach efforts to educate homeowners and contractors about how to operate an ASHP system to optimize energy efficiency without sacrificing comfort.

Utilities should consider a tune-up program that is customer-driven. To help decrease freeridership, the utilities should present marketing materials to customers that stress the importance and potential energy savings of utility-sponsored tune-ups, thereby increasing customer demand for program-qualifying tune-ups. Doing so might also recruit HVAC systems with poor operating efficiency because owners of these systems otherwise would not have received a tune-up. Utility-driven marketing to customers will minimize the likelihood that contractors submit applications for tune-up rebates for HVAC systems that already have standard maintenance agreements (between the contractors and their customers).

Appendix A: Detailed Program Descriptions

A.1. BGE

BGE's Residential HVAC program seeks to increase the energy efficiency of HVAC equipment installed in its residential service territory. To accomplish this goal, BGE's HVAC program influences the market's demand and supply by:

- Incenting sales and educating homeowners so they will demand higher efficiency HVAC equipment and installation; and
- Involving contractors to increase their efforts to supply such equipment and quality servicing.

The program includes these measures: HVAC system equipment replacement, gas furnaces, duct sealing, and A/C efficiency boosters (tune-ups).

The program strategies are as follows: (1) educate the general public and homeowners on the benefits of high-efficiency equipment and high-quality servicing (e.g., duct sealing, efficiency tune-ups and quality installation; (2) offer financial incentives to homeowners to install the equipment or obtain duct sealing or tune-up services; (3) require equipment to meet minimum efficiency standards such as those in the Air Conditioning Contractors of America (ACCA) Manual J (or similar sizing standards) to qualify for the incentive; and (4) provide incentives and training to HVAC contractors to encourage full participation and to assist with customer sales.

The HVAC program targets two major markets:

- ***Residential customers/homeowners*** who are purchasing new CAC or heat pump (HP) equipment to replace existing equipment or to improve their homes.
- ***HVAC contractors and distributors*** who serve residential customers and homeowners in Maryland**.**

Table 21 lists incentives for program measures.

Table 21. BGE HVAC Program Measures and Incentives (EY4)

Measures	Incentives
Gas Furnace Tier 1: ≥ 92% AFUE w/ECM or equivalent	$300
Gas Furnace Tier 2: ≥92% AFUE w/ECM + QIV	$400
Central AC Tier 1: ≥14.5 SEER, ≥12 EER	$150
Central AC Tier 2: ≥15 SEER, ≥12.5 EER	$300
Central AC Tier 3: ≥16 SEER, ≥13 EER	$500
Air-Source HP Tier 1: ≥14.5 SEER, ≥12 EER, ≥8.2 HSPF	$200
Air-Source HP Tier 2: ≥15 SEER, ≥12.5 EER, ≥8.5 HSPF	$300
Air-Source HP Tier 3: ≥16 SEER, ≥13 EER, ≥9 HSPF	$500
Geothermal HPs (closed loop): ≥17.1 EER, ≥3.6 COP	$500
Ductless Mini Split AC: ≥16 SEER, ≥13 EER	$300
Ductless Mini Split HP: ≥16 SEER, ≥13 EER, ≥9 HSPF	$300
A/C Efficiency Booster (Tune-Up)	$100
Duct Sealing	$250

Source: BGE Website

A.2. Pepco Holdings, Inc. (Pepco & DPL)

Pepco and DPL developed their Residential HVAC Efficiency Programs to increase the energy efficiency of CAC and HP equipment installed in their residential service territories. To meet this goal, Pepco and DPL incent homeowners to demand higher-efficiency HVAC equipment and trade allies to supply and sell more program-qualifying equipment.

The program targets two major groups:

- ***Residential customers*** who are purchasing new central air conditioning or HP equipment either to replace existing equipment, to improve their existing home, or for a newly-constructed home.
- ***HVAC contractors and distributors.***

The specific program strategies are to: (1) educate the general public and homeowners on the benefits of high-efficiency equipment and quality installations; (2) offer financial incentives to homeowners to install high-efficiency equipment or to obtain duct sealing or tune-up services; (3) require equipment to meet minimum energy efficiency standards such as ACCA Manual J (or similar sizing standards) to qualify for the incentive; and (4) provide HVAC contractors with training opportunities to help ensure high-quality installation practices.

Table 22 lists incentives for key program components.

Table 22. Pepco and DPL HVAC Program Measures and Incentives (EY4)

Measures	Incentives
Central AC: ≥14.5 SEER, ≥12 EER	$150
Central AC: ≥15 SEER, ≥12.5 EER	$300
Central AC: ≥16 SEER, ≥13 EER	$500
Air-Source HP: ≥14.5 SEER, ≥12 EER, ≥8.2 HSPF	$200
Air-Source HP: ≥15 SEER, ≥13 EER, ≥8.5 HSPF	$300
Air-Source HP: ≥16 SEER, ≥12.5 EER, ≥9 HSPF	$500
Geothermal HPs (closed loop): ≥17.1 EER, 3.6 COP	$500
Ductless Mini Split AC: ≥16 SEER, ≥13 EER	$300
Ductless Mini Split HP: ≥16 SEER, ≥13 EER, ≥9 HSPF	$300
AC or HP System Tune-Up	$100
Duct Sealing	$250

Source: Pepco and DPL Websites

A.3. PE

PE's Residential HVAC program seeks to increase the adoption and market share of high-efficiency CAC and HP equipment in PE's residential service territory. To meet this goal, PE influences the HVAC market's demand and supply sides. The program educates and incents homeowners to demand higher-efficiency HVAC equipment and installation and educates trade allies to promote and supply such equipment.

The program targets two major groups:

» ***Residential customers*** who are purchasing new central air conditioning, HPs, or water heating equipment when either replacing equipment in their homes or obtaining equipment for new homes.
» ***HVAC Contractors.*** Contractors influencing the customers' decisions to purchase high-efficiency equipment.

The specific program strategies are as follows: (1) educating customers and encouraging participation through a marketing plan, Website, and information materials; (2) offering financial incentives to homeowners to install energy-efficient HVAC equipment; (3) conducting outreach activities to HVAC contractors and developing a participating contractor network to market the program to customers; and (4) maintain a contractor network to encourage participation.

Table 23 lists the incentives for key program components.

Table 23. PE HVAC Program Measures and Incentives (EY4)

Measures	Incentives
Central AC Tier 1: ≥14.5 SEER, ≥12 EER	$150
Central AC Tier 2: ≥15 SEER, ≥12 EER	$300
Central AC Tier 3: ≥16 SEER, ≥12 EER	$500
Air-Source HP Tier 1: ≥14.5 SEER, ≥12 EER, ≥8.5 HSPF	$200
Air-Source HP Tier 2: ≥15 SEER, ≥12 EER, ≥8.5 HSPF	$300
Air-Source HP Tier 3: ≥16 SEER, ≥12 EER, ≥8.5 HSPF	$500
Geothermal HPs (closed loop): ENERGY STAR qualified	$500
Ductless Mini Split AC: ≥15 SEER, ≥12 EER	$300
Ductless Mini Split HP: ≥15 SEER, ≥12 EER , ≥8.5 HSPF	$300
Whole House Fan (in homes with CAC or HP), 1000 CFM	$100
HVAC Tune-Up	$100
HVAC Tune-Up with ECM Furnace Fan Installation	$140

Source: PE Website

A.4. SMECO

SMECO's High Efficiency HVAC and Water Heating Equipment Program seeks to increase both the operational efficiency of existing HVAC equipment and the sales of high-efficiency HVAC equipment in the utility's residential service territory. SMECO influences both the demand and supply sides of the HVAC market. The utility educates and incents homeowners to demand higher-efficiency HVAC equipment and trade allies to sell more program-qualified equipment.

The specific program strategies are to: (1) educate the general public, homeowners, and contractors on the benefits of high-efficiency equipment and high-quality installation; (2) offer financial incentives to homeowners to install the equipment, or obtain duct sealing or tune-up services; (3) require the equipment to meet minimum energy efficiency standards such as those in the ACCA Manual J (or similar sizing standards) to qualify for the incentive; and (4) secure participation of a group of trained, quality-focused HVAC contractors to implement program benefits and a broader group of contractors to promote measures.

The target market consists of two major groups:

» ***Residential customers*** who are purchasing new central air conditioning or HP equipment to replace existing equipment or improve their current home.
» ***HVAC contractors.*** Select HVAC distributors and manufacturers are also engaged.

Table 24 lists incentives for key program components.

Table 24. SMECO HVAC Program Measures and Incentives (EY4)

Measures	Incentives
Central AC Tier 1: ≥14.5 SEER, ≥12 EER	$150
Central AC Tier 2: ≥15 SEER, ≥12.5 EER	$300
Central AC Tier 3: ≥16 SEER, ≥13 EER	$500
Air-Source HP Tier 1: ≥14.5 SEER, ≥12 EER, ≥8.2 HSPF	$200
Air-Source HP Tier 2: ≥15 SEER, ≥12.5 EER, ≥8.5 HSPF	$300
Air-Source HP Tier 3: ≥16 SEER, ≥13 EER, ≥9 HSPF	$500
Geothermal HPs (closed loop) ≥17.1 EER, ≥3.6 COP	$500
Ductless Mini Split AC: ≥16 SEER, ≥13 EER	$300
Ductless Mini Split HP: ≥16 SEER, ≥13 EER, ≥9 HSPF	$300
Performance Tune-Up	$100
Duct Sealing	$250

Source: SMECO Website

Appendix B: Gross Impact Measurement and Verification Methodology

Central air conditioners (CAC) and air-source heat pumps (ASHP) are the only two residential HVAC measures that the EmPOWER utilities have bid into PJM's forward capacity market. This section briefly describes the measurement and verification (M&V) methods used to verify the PJM coincident peak savings for these measures.

For a more complete description of these methodologies, or descriptions of the methodologies for all other measures, please see Appendices D and E (pages 29 and 32).

B.1. Central Air Conditioner and Air-Source Heat Pump Metering

To assess the PJM coincident demand impacts for CACs and ASHPs, the team used PJM's Manual 18B Option A: "Partially Measured Retrofit Isolation/Stipulated Measurement."[9] This method corresponds with Option A of the International Performance Measurement and Verification Protocol (IPMVP) manual.

The team performed the following M&V activities in 2010 (EY1) and 2012 (EY3) for CACs and in 2012 and 2013 (EY4) for ASHPs. For the EY3-EY4 study the meters were installed at the end of July 2012 and removed in October. Heat pump meters were installed at the end of July 2012 and remained in place for the heating season (through Spring 2013).

- Spot-measured and logged the true power of the AC or heat pump condenser for a random sample of program participants at a two-minute interval (consumption, demand, and hours-of-use data in a single measurement).
- Using solar-shielded sensors, logged outdoor temperatures in the vicinity of condensers.
- Spot-measured the true power, volts, amps, and power factor of indoor fans.
- Logged fan currents and the backup electric resistance heater plate current of heat pumps at two-minute intervals.
- Logged indoor and outdoor temperature and relative humidity at two-minute intervals.

[9] PJM Forward Market Operations, PJM Manual 18B: Energy Efficiency Measurement & Verification, Effective date: March 1, 2010

Appendix C: Applicable Codes, Standards, and Baselines

Typically, utilities have either adopted the Mid-Atlantic TRM savings calculation method or used variations of the TRM savings algorithm that provide similar energy and demand savings values.[10] The TRM uses the following assumptions for baseline CAC ASHP, and GSHP equipment:

- For CACs and ASHPs, the minimum seasonal energy efficiency ratio (SEER) rating is 13.
- For ASHPs, the minimum heat seasonal performance factor (HSPF) rating is 7.7.
- For GSHPs, the minimum heating and cooling efficiency is 14.1 EER

The energy savings analysis discussed in this report assumes that in the program's absence, customers would have installed a CAC or ASHP meeting the federal minimum efficiency requirements described above. The analysis assumes a customer installing a GSHP would have installed a 14.1 EER (Tier 1) GSHP.

In the utility tracking databases, the team found no evidence of any heat pump participants who switched from gas heat to heat pumps—a situation that could result in increased electricity consumption and negative savings.

[10] NEEP, Mid-Atlantic Technical Reference Manual, Version 3.0. March 2013

Appendix D: Detailed Gross Impact Evaluation – Verification Activities

In EY4, the evaluation team conducted phone interviews and on-site metering to verify measure installation and monitor the seasonal performance of CAC and ASHP equipment. In both cases, all respondents (100%) recalled installing equipment through the program ***and*** are still using the rebated equipment in their homes.

D.1. Participant Phone Survey

Because equipment measures account for the largest portion of the EmPOWER Residential HVAC programs' energy savings, the evaluation team surveyed 101 participating customers who installed equipment measures between June 1, 2012, and May 31, 2013: 25 each from BGE, PE, and SMECO territories, and 13 each from Pepco and DPL. The team created a random sample from each utility's tracking data that assured proportional representation of each equipment measure type. Pacific Market Research fielded the survey from late September through early October 2013.

The survey included three questions to determine if the customers remembered installing the measure, if the measure was still installed, and if the customer was still using the measure. (See Section A of the participant survey in Appendix H, page 87, for the verification battery.) All respondents recalled installing the equipment and confirmed that they are still using it.

D.2. On-Site Verification and Metering

Central air conditioners (CACs) and ASHPs account for a large portion of energy and peak demand savings for EmPOWER HVAC rebate programs. During EY3 and EY4, the team visited 44 ASHP and CAC sites to measure the installed systems' seasonal performance. During these visits, the team also verified that 100% of the systems were in place and that the AHRI certificate of each system matched program records, indicating the SEER rating reported matched the efficiency of the installed system.

Table 25 shows the total number of meter installations for each utility, including sites from the EY1 metering study. The CAC meters were installed at the end of July 2012 and removed in October. Heat pump meters were installed at the end of July 2012 and remained in place for the heating season (through Spring 2013). The meter data collected during the heating season was combined with the ASHP metered data from the 2010 study and used to update the ASHP heating savings as described in Section E.5.

Table 25. Total Meter Installations by Utility*

Utility	Year	ASHPs	CACs
BGE	2010	12	16
Pepco	2012	2	14
SMECO	2012	10	1
DPL	2012	0	1
PE	2012	5	9
Total		29	41

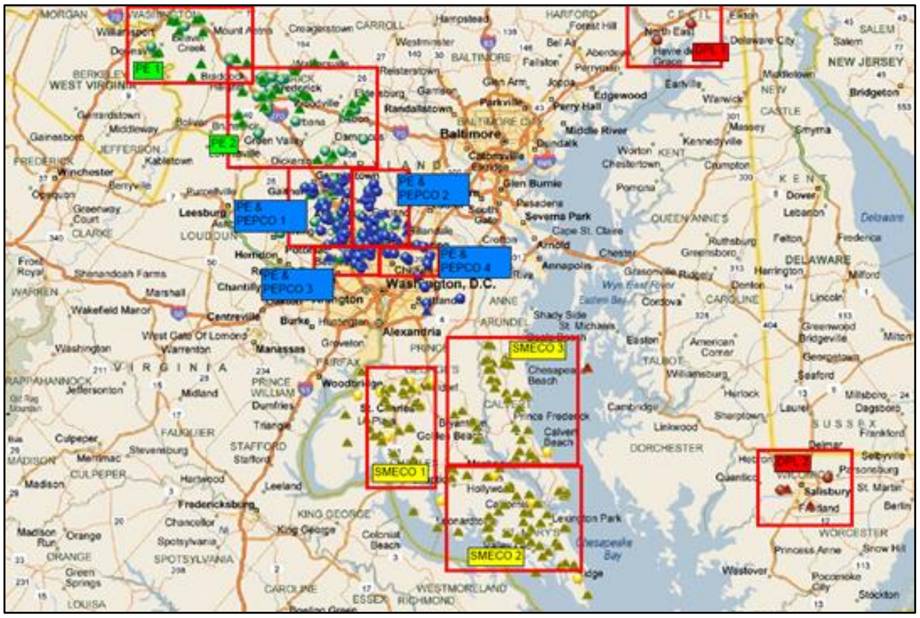
*Two data sets removed because meters were damaged

PJM Manual 18B specifies four weather zones in which EmPOWER utilities operate, and the evaluation team took a random sample from the three weather zones not yet metered. These weather zones encompass Pepco and SMECO (they are in the same zone), DPL, and PE. The 2010 metering study provided energy and demand savings for ASHPs and CACs for BGE only, while the 2012 metering study expanded the effort to include ASHP and CAC metering in weather zones that had not been metered.

The team selected a sample to achieve 10% relative precision with a one-tailed test at the 90% level of confidence at the statewide level. The sample size of 44 units is based on an estimated coefficient of variation of 0.6. In the sample distribution, shown in Figure 2, blue and green labels represent PE and Pepco, yellow labels represents SMECO, and red labels represent DPL. (The red squares designate clusters used for scheduling the site visits.)

To increase accuracy and precision of evaluated savings, the team combined the results of the 2010 metering study with the results from the 2013 metering study.

Figure 2. Random Sample of ASHP and CAC Metering Participants



Appendix E: Detailed Gross Impact Evaluation – Measurement and Other Parameter Update Activities

This section describes the evaluation activities performed during EY4 to update the evaluated gross savings.

E.1. Tune-Up Engineering Review

E.1.1. Tune-Up Methodology

Central air conditioner (CAC) and ASHP tune-ups save energy by improving system efficiency. To determine the efficiency improvement from tune-up measures, the team reviewed applications, contractor invoices, and contractor worksheets provided by each utility described in section E.1.3. The team used the equivalent full load hours for each utility for CACs and ASHPs to determine the energy consumption of an HVAC unit.

Information reported varied across utility programs and contractors. In general, the team looked for the following information to calculate savings for each measure reviewed:

» System type (CAC or ASHP)
» System size (tons)
» Whether an airflow adjustment was performed
» Whether a refrigerant charge was adjusted
» Whether a coil cleaning was performed
» Reported efficiency index (EI) (pre- and post-installation)

The team counted zero savings if the contractor worksheet indicated the HVAC system was operating correctly or that limited or no work was performed to improve system efficiency. [11]

If the contractor provided pre- and post-installation efficiency measurements, the team used the efficiency improvement to estimate savings. Because tune-up program data is different for each utility, the team performed an engineering review of all relevant data. This also included a review of the methods used to determine the efficiency index. The engineering review is described below.

[11] The only consistent example of "limited" work is filter change. If the contractor claimed the filter was changed, the team did not give savings credit.

E.1.2. Tune-Up Analysis

Efficiency Index

The utilities use a metric called the efficiency index (EI) to report system efficiency before and after tune-ups. The EI is the ratio of *measured performance* to *expected performance*, values determined by the field diagnostic service assistant (FDSI). The FDSI methods for estimating compressor capacity and EI are described in US Patent No. 6,701,725: "Estimating operating parameters of vapor compression cycle equipment[12]."

FDSI uses a proprietary model to develop expected values for a system that is properly tuned. Expected values of the performance indices (evaporating temperature, super-heat, condenser over ambient temperature, and sub-cooling) are determined from using the system characteristics (system type, expansion device, and rated cooling efficiency) and independent operating parameters (return air temperature, return air wet bulb, and outdoor temperature). Ultimately, the FDSI estimates these "expected performance values:" cooling capacity and power.

FDSI also estimates *measured performance* from compressor maps using actual contractor measurements of the system. To obtain the measured performance values requires only common and easily obtainable contractor measurements. The measurements are:

- Liquid or discharge pressure
- Suction pressure
- Liquid line temperature
- Suction line temperature
- Condenser air entering temperature

Generic compressor map coefficients are used to estimate both refrigerant mass flow through the compressor and compressor power.

The evaluation team reviewed the calculation methodology and found that the algorithms and logic are sound and rigorous. The team used the EI measurements to estimate energy savings with the following algorithm:

$$\Delta kWh = rating\ of\ unit\ (tons) \times EFLH_{cooling} \times \left(\frac{12}{EER_{before}} - \frac{12}{EER_{after}}\right)$$

[12] For verification and evaluation of this methodology, see http://www.puc.pa.gov/pcdocs/1154040.pdf page 190-198

Where

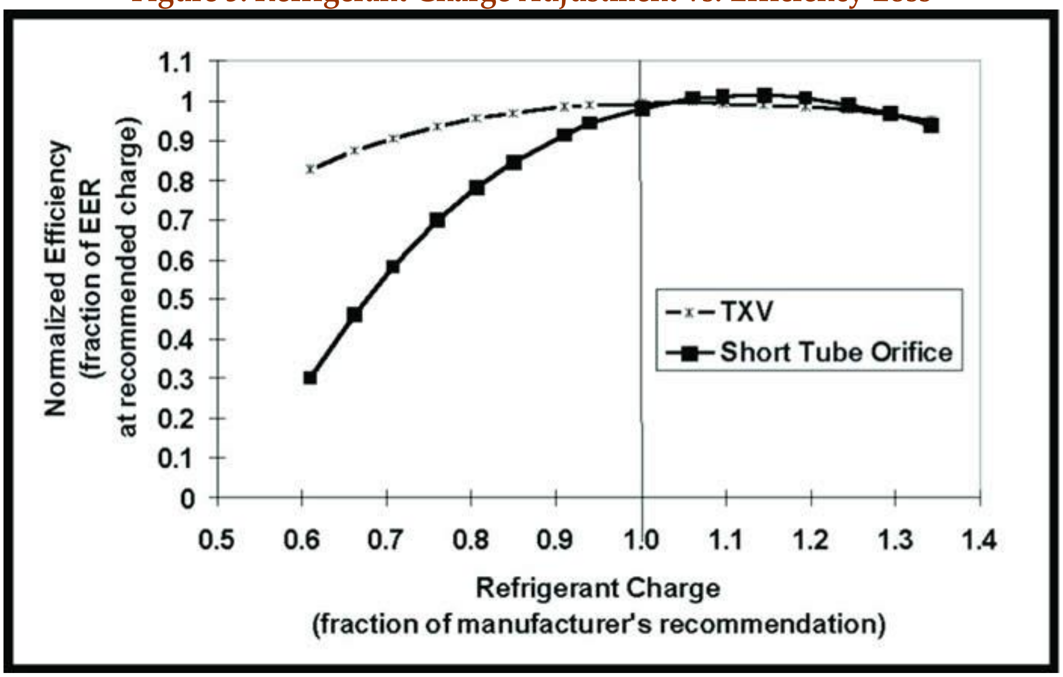
$EER_{before} = \text{EI}_{pre} \times \text{nameplate EER}$

$EER_{after} = \text{EI}_{post} \times \text{nameplate EER}$

Refrigerant Charge Adjustment as a Basis for Estimating Efficiency Improvement

If a refrigerant charge adjustment is performed on a system, the team used the reported data and known relationship between refrigerant charge adjustment and efficiency improvement. With known nameplate rated charge and the amount of refrigerant added or removed, the team calculated the fraction of manufacturer nameplate rated charge (x-axis in Figure 3). The relationship between refrigerant charge and efficiency improvement is represented in Figure 3.

Figure 3. Refrigerant Charge Adjustment vs. Efficiency Loss



Source: http://www.proctoreng.com/utilities/Charge.html

Savings due to refrigerant charge were calculated using the following algorithms:

$$EER_{before} = (1 - eff\ loss) \times EER_{nameplate}$$

$$\Delta kWh = rating\ of\ unit\ (tons) \times EFLH_{cooling} \times \left(\frac{12}{EER_{before}} - \frac{12}{EER_{nameplate}}\right)$$

Where Detailed Measurements Are Not Available

The TRM does not provide a tune-up savings algorithm or a deemed savings estimate. To arrive at an estimate for instances where detailed measurements are not available, the evaluation team drew upon the mid-Atlantic TRM to determine a baseline efficiency SEER value to use in the algorithms described above. For HVAC systems built before 2006, the Mid-Atlantic TRM estimates efficiency as 10 SEER.[13] The evaluation team accepts that this reasonably represents the efficiency of the typical units that receive a tune-up through the EmPOWER HVAC programs.

The team calculated energy consumption of a 10 SEER system using the equivalent full load hour (EFLH) value metered for each utility. If a coil cleaning was performed but no pre-/post-tune-up measurements were provided, the team assumed 5% efficiency improvement. The team assumed coil cleaning saves 5% total energy and 5% demand as this is common for TRMs in other states.[14] If airflow was corrected, the team assumed 5% savings. If both the condenser coil was cleaned and airflow was adjusted, that tune-up received 10% savings.

In some instances, the document review showed the HVAC contractor reported that the system was operating as expected and no tune-up work was required but that the filter was changed. The team assumed 0 savings for filter replacement.

The energy savings were calculated as follows:

$$kWh\ saved = \frac{Utility\ EFLH \times 12{,}000\frac{BTU}{ton}}{SEER} \times \%\ savings$$

The evaluation team calculated utility peak demand and PJM peak demand savings using similar methods. From the Mid-Atlantic TRM, the team used coincidence factors of 0.66 for PJM and 0.69 for utility defined HVAC system demand savings.

E.1.3. Tune-Up Findings

Evaluated tune-up savings varied across utilities depending on the work performed and reported by contractors. The evaluation team found differences in tune-up savings across the five utilities, with an average of 3.7% efficiency improvement for a tune-up. In the utility-specific subsections below we compare the utility's evaluated tune-up savings to the average tune-up. The total evaluated savings are provided in Section E.6. This section also describes the evaluation differences for each utility.

[13] Page 95 of TRM Version 3.0

[14] Reference: Massachusetts TRM, 2010 Ohio Technical Reference Manual, August 6, 2010, Arkansas TRM Vol. 2.0.

BGE

BGE reported 24 total tune-ups. BGE provided detailed worksheets and contractor invoices for 18 tune-ups. The team used all available reported data to develop a best-estimate savings value by using a combination of all three methods described above. Only one reported measure used the EI pre-/post-tune-up method.

A BGE tune-up saved 40% less energy than the average savings of all five utilities. The team's review of BGE's reported documentation indicated very little work was performed on most units. Only five of the 18 units received condenser cleaning and one unit received refrigerant charge adjustment. The rest of the tune-up measures reported indicated the system was operating properly and did not require service work.

Pepco

Pepco reported 420 total tune-ups. Pepco provided detailed worksheets and contractor invoices for 30 tune-ups. The team used all available reported data to develop a best savings estimate. All of the measurements within the sample included pre- and post-tune-up EI so this was used to calculate savings directly for each reported tune-up.

A Pepco tune-up saved 51% less energy than the average savings of all five utilities. The team's review of Pepco's reported documentation found a higher proportion of CACs than ASHPs received tune-ups, and CACs have less savings potential. Of the HVAC units receiving a tune-up, 57% reported 0 kWh savings. The average efficiency improvement of the rest of the HVAC units serviced was 6%.

DPL

DPL reported 40 total tune-ups. DPL provided detailed worksheets and contractor invoices for 32 tune-ups. The team used all available reported date to develop a best savings estimate by using a combination of all three methods described above. Many of the measurements included pre- and post-tune-up EI so this was used to calculate savings directly for each reported tune-up.

A DPL tune-up saved nearly three times more energy than the average savings of all five utilities. The team's review of DPL's reported documentation used pre and post-efficiency measurements to estimate savings. The average improvement in efficiency of all measures was approximately 9%.

PE

PE reported 3,963 total tune-ups in EY4 and provided 90 tune-up files for the evaluation team to review. PE does not report pre- and post-tune-up efficiency data. The team reviewed all of these files and invoices to determine what work was performed on each system. The team assumed 5% savings when the contractor cleaned the coil or adjusted airflow. The PE tune-up worksheets reviewed by the evaluation team provide refrigerant charge adjustment amount so the team used this information to calculate savings using the correlation between refrigerant charge adjustment and efficiency improvement.

A PE tune-up saved about the same, on average, as the average savings of all five utilities. About half of PE's tune-ups showed measures performed improved efficiency. Nearly all PE tune-ups were ASHPs, resulting in greater savings potential.

SMECO

SMECO reported 42 total tune-ups. SMECO provided 22 tune-up files. SMECO does not report pre- and post-tune-up efficiency data. None of the SMECO worksheets and invoices had information about work performed. For a SMECO tune-up, the evaluation team used the average savings from the other utilities: 3.7% savings improvement.

E.2. Central AC, Ductless Mini-Split Systems, and Ground-Source Heat Pump Engineering Review

The evaluation team used similar methods to determine gross evaluated savings for CAC, ductless mini-split, and GSHP measures.

The team used utility-reported data and evaluation results from the EY3 metering study to estimate CAC savings.

The team used the following algorithm to estimate savings for central ACs and ductless mini-split ACs:

$$\Delta kWh = rating\ of\ unit\ (tons) \times utility\ EFLH_{cooling} \times \left(\frac{12}{SEER\ 13} - \frac{12}{SEER_{installed}}\right)$$

To estimate demand savings the team used the per-ton demand savings values listed in Table 20. The utility-reported inputs are:

- Tons
- SEER
- EER

If an input was missing, the team used the average from all other reported CACs in the same measure category.

Similarly, the team used utility-reported data and evaluation results from the EY3 metering study to estimate savings for mini-split heat pump and GSHP measures. For cooling savings, the team used updated cooling EFLH values for each utility, based on results of the EY3 study. The team updated heating EFLH based on results from the EY4 evaluation to estimate heating savings (see Table 30).

The team used the following algorithm to estimate savings for GSHPs and ductless mini-split HPs:

$$\Delta kWh = rating\ of\ unit\ (tons) \times \left[utility\ EFLH_{cooling} \times \left(\frac{12}{SEER\ 13} - \frac{12}{SEER_{installed}}\right) + utility\ EFLH_{heating} \times \left(\frac{12}{HSPF\ 7.7} - \frac{12}{HSPF_{installed}}\right)\right]$$

The utility-reported inputs are these:

- Tons
- SEER
- EER
- HSPF
- Coefficient of performance (COP)[15]

Because of the GSHP incentive level, the evaluation team felt that a GSHP was a more reasonable baseline for that measure than the previously-use ASHP baseline. Therefore, the team replaced SEER 13 and HSPF 7.7 with EER 14.1 – the ENERGY STAR Tier 1 GSHP efficiency. Only one efficiency value was used for both heating and cooling because utilities provide only one EER value.

To estimate demand savings the team used the per-ton demand savings values listed in Table 20. Again, if an input was missing the team used the average from all other reported systems in the same measure category.

[15] If both EER and COP were provided, EER is used for kW and cooling savings estimation and COP is used for heating savings.

E.3. Duct Sealing Engineering Review

BGE and Pepco reported duct sealing savings from their HVAC programs. Since the utilities reported only 66 duct sealing measures, the team checked the reported savings for reasonableness.

The reported savings are based on contractor measurements of CFM reduction.

The evaluation team compared the reported savings to a savings value estimated from the engineering review. To estimate duct sealing savings, the team assumed duct sealing saves 14% energy and demand. This is the minimum threshold for savings for many programs.[16] The team chose 14% because it is conservative and because the TRM requires duct leakage improvement values (actual pre-/post-sealing CFM reduction). It is important to note the location of ducts and type of testing performed to fully understand the realistic savings potential.

The evaluation team's analysis assumes the following to calculate a reasonable savings estimate (note the second term of the equation is applicable only to heat pumps:

$$savings\ (kWh) = 14\%\ x\ \left[\frac{EFLH_{cooling} \times tons \times 12}{SEER} + \frac{EFLH_{heating} \times tons \times 12}{HSPF}\right]$$

This analysis methodology assumes all conditioned air lost through duct leakage is lost (i.e., does not contribute to space conditioning). If ducts are located outside conditioned space like in an attic or crawlspace under the home, this methodology reasonably represents savings. But if ducts are located in the basement, the methodology may overestimate savings.[17] According to a study by Lawrence Berkeley National Laboratory (LBNL),[18] if ducts are located in a basement, the equation above is inaccurate. This is because some of the air leaked is either regained through leaks in the return or the leaked air makes its way into the home. This study suggests duct air distribution efficiency improvement (savings improvement) from sealing ducts in an unconditioned basement is closer to 5%.

The duct sealing information tracked by the utilities does not provide specific information about either the ducts' location or the relative leakage rates (leakage to the outside or simply total duct leakage).

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[16] E.g. NV Energy, Ameren MO, Gulf Power.

[17] Basement is defined as part of the shell of the home, which means the basement is accessible through a door in the interior of the home.

[18] "Sensitivity of Forced Air Distribution System Efficiency to Climate, Duct Location, Air Leakage and Insulation" LBNL 43371.Online: http://energy.lbl.gov/ied/pdf/LBNL-43371.pdf

The savings reported seem conservative for heat pumps if 14% leakage reduction is achieved (average of 166 kWh for HPs). Although the savings are high for CACs (average of 379 kWh savings achieved),[19] the team accepts the reported savings, which show 19% leakage reduction.[20]

E.4. ECM Engineering Review

BGE reports energy savings from electronically commutated motor (ECM) installation in new high efficiency furnaces. PE also reported ECM savings in a measure coupled with an HVAC Tune-Up. The team planned to use fan meter data from the ASHP metering activities conducted in EY3 and EY4. In these metering sites, 70% of the ASHP systems used fans with electronically commutated motors (ECM), and 30% used standard, permanent split capacitor (PSC) fan motors.

ECMs save significant energy when operating in circulation mode but save much less energy in heating and cooling mode. Furthermore, the SEER and HSPF ratings already account for heating and cooling interactive effects of ECMs so it is possible to double-count savings when ECMs are installed with high efficiency heat pumps or CACs.

The evaluation team reviewed the circulation mode runtimes of ECM fans and found six homeowners operated their fans continuously (or nearly so). Only one homeowner operated a PSC fan continuously.

As only one PSC motor operated in continuous mode, the evaluation team could not report impacts from the EY3 metering study. Additional research of a larger sample of PSC fan motors would be required to estimate a reasonable baseline. Currently, the data indicate that on average an ECM fan consumes more energy than a PSC fan as ECM fans run longer. In numerous jurisdictions, the evaluation team has observed that HVAC contractors tell homeowners to operate their ECMs in continuous mode, as the fan uses very little power and such operations improve air quality and effectively distribute temperatures throughout the home.

Estimating ECM impacts would require the following evaluation research:

- For operators exhibiting continuous ECM fan use, determining:
    - If they ran their old fan continuously; and

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[19] Savings assessed based on 14% leakage realized and unit energy consumption using EFLH and 10 SEER AC and ASHP of 10 SEER, 6.8 HSPF.

[20] 19% leakage reduction was estimated by dividing the average reported savings (379 kWh) by the unit energy consumption for a 10 SEER system.

  - If they would run a new, standard-efficiency fan in circulation mode continuously.
- Directly metering additional PSC fans or surveying homeowners with PSC fans to determine how often they run the fans in circulation mode.

In the engineering review, the team found that the ECM savings reported were reasonable compared to savings claimed in other programs,[21] and the team thus accepts the reported savings. However, the evaluation team assumes 0 kW peak demand savings for the following reasons:

1) The Mid-Atlantic TRM assumes 162.5 Watts saved during periods of peak demand. The TRM source states: The average delta watts power draw for a furnace with ECM compared to without is 162.5W, from Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study," Technical Report 230-1, October 2003, p34. The evaluation team has reviewed this report in detail. The demand savings are estimated from a total of 12 furnaces with ECM fans and 13 with standard fans. The team considers the difference in peak demand speculative because the peak period was not metered. In the team's experience, ECM fans tend to draw similar power to PSC motors when in high-speed cooling mode.
2) The majority of ECM incentives were provided for gas furnace measure installations. The team was unable to confirm whether the gas furnace was installed with a cooling system, therefore could not confirm that the ECM would be operating during peak hours.
3) As noted above, the team found only one standard PSC fan ran continuously in cooling mode while six ran the ECM fan continuously. Intuitively this means PSC fans might have lower energy consumption during periods of peak cooling; however, further research is needed to confirm this theory.

E.5. Air-Source Heat Pump Metering and Engineering Review

E.5.1. ASHP Savings Analysis Methodology

The evaluation team evaluated ASHP savings according to International Performance Measurement and Verification Protocol (IPMVP) Option A. This method included the following metering activities for a random sample of program participants:

- Spot-measured and logged the ASHPs' true power (this provided consumption, demand, and hours-of-use data using a single measurement),

[21] For example, Wisconsin Focus on Energy claims ~700 kWh for ECM installation.

- Logged outdoor temperatures in the vicinity of heat pump condensers using solar-shielded sensors,
- Spot-measured the true power, volts, amps, and power factors of indoor fans.
- Logged fan currents and estimated power with spot measurement of voltage and power factor.
- Logged backup electric resistance heat and used spot measurement of voltage to calculate power.[22]

The team used the metered data, manufacturers' data, and the following assumptions to determine the annual energy savings for the installed ASHP units.

- The baseline model is a 13 SEER, 7.7 HSPF, code-compliant ASHP
- The baseline system would have provided an equivalent heating capacity, but at a lower efficiency.
- Use of backup heat would remain the same for baseline and high-efficiency units.[23]
- ASHPs would be sized in the same way across all utilities[24].

Figure 4 provides an example of a manufacturers' specification sheet.

Figure 4. Example of a Manufacturer's ASHP Specification Sheet

INDOOR AIR		OUTDOOR COIL ENTERING AIR TEMPERATURES °F (°C)														
		−3 (−19.4)			7 (−13.9)			17 (−8.3)			27 (−2.8)			37 (2.8)		
EDB °F (°C)	CFM	Capacity MBtuh		Total Sys. KW†	Capacity MBtuh		Total Sys. KW†	Capacity MBtuh		Total Sys. KW†	Capacity MBtuh		Total Sys. KW†	Capacity MBtuh		Total Sys. KW†
		Total	Integ*		Total	Integ*		Total	Integ*		Total	Integ*		Total	Integ*	
25HCC518A30 Outdoor Section With FX4DNF019 Indoor Section																
65 (18.3)	525	5.13	4.72	1.02	7.34	6.75	1.07	9.76	8.90	1.12	12.54	11.13	1.18	15.15	13.78	1.24
	600	5.22	4.80	1.02	7.46	6.85	1.07	9.91	9.03	1.11	12.68	11.27	1.17	15.35	13.97	1.22
	675	5.30	4.87	1.02	7.55	6.94	1.07	10.04	9.15	1.11	12.80	11.37	1.16	15.51	14.12	1.20
70 (21.1)	525	4.84	4.45	1.07	7.04	6.47	1.12	9.43	8.60	1.18	12.28	10.90	1.24	14.86	13.52	1.31
	600	4.92	4.53	1.07	7.15	6.57	1.12	9.58	8.74	1.17	12.44	11.04	1.23	15.05	13.70	1.28
	675	4.99	4.59	1.07	7.25	6.66	1.12	9.71	8.85	1.16	12.56	11.16	1.21	15.21	13.84	1.26
75 (23.9)	525	4.50	4.14	1.11	6.70	6.16	1.17	9.09	8.29	1.23	11.98	10.64	1.30	14.56	13.25	1.37
	600	4.59	4.22	1.12	6.82	6.27	1.17	9.24	8.42	1.22	12.15	10.79	1.29	14.75	13.43	1.34
	675	4.66	4.29	1.12	6.92	6.36	1.17	9.36	8.54	1.22	12.29	10.91	1.27	14.91	13.57	1.33

Manufacturers list the output heating capacity (in MBtuh) and total compressor system power (kW) for multiple outdoor air temperatures. The evaluation team used this information to develop COP vs. outdoor temperature equations for each installed system, including adjustments for matched indoor coils[25]. The team assumed 70°F indoor air temperature for

[22] Power factor of electric resistance heat load is 1.0.

[23] This assumption is made because there is no installation requirement of backup heat control setpoints or electric resistance strip heat lock-out

[24] HVAC contractors might select a heat pump for the heating load or the cooling load therefore changing the HVAC system size per sq foot from one region to the next. The analysis assumes contractors size heat pumps in the same way for all regions.

[25] Manufacturers list capacity adjustment factors for indoor evaporator coils matched with hundreds of condenser combinations.

heating (middle three rows in Figure 4) and 75°F indoor air temperature for cooling. Although the total system power does not include power consumption of the backup electric resistance heater plates, the evaluation analysis assumed electric resistance energy consumption would have been the same for the baseline system.

The evaluation team estimated savings for meter interval 'i' and temperature 'T' as follows:

$$Energy\ Savings = \sum \left(Metered\ Energy\ Use_i \times \frac{high\ COP\ HP(T_i)}{base\ COP\ HP(T_i)} \right) - Metered\ Energy\ Use_i$$

Where:

i = 2-minute metering interval, from the fall and winter of 2012 through the end of April 2013

Ti = Outdoor air temperature for interval i based on logged temperature data at each site

Metered Energy Use$_i$ = Metered energy consumption over interval i for the installed ASHP

High COP HP (T_i) = Estimated COP at temperature T_i, based on the COP vs. temperature curve for the installed ASHP.

Base COP HP (T_i) = Estimated COP at temperature T_i, based on the COP vs. temperature curve for the baseline ASHP.

E.5.2. ASHP Data Collection

The evaluation team metered over 175 days of data for 16 ASHP systems during the 2012/2013 heating season. Table 26 summarizes the in-field findings for these systems, as well as the 14 systems metered during the 2010/2011 heating season (for the EY1 report). The table shows that units metered in EY4 ranged from 1.0 to 4.0 tons of capacity, with all but three units using electric resistance as backup heat.

In EY3—when the ASHP metering sample was chosen—BGE heat pump installations represented 70% of the total heat pumps installed across all EmPOWER utilities. Pepco and SMECO, with similar weather, represented 21% of all heat pump installations. PE had 7% of the portfolio's heat pump installations, while DPL had 2%. The team did not meter any sites in DPL's service territory.

Table 26. Summary of Systems Metered in EY1 and EY3-EY4

Site #[a]	Utility[b]	Tons	SEER[c]	HSPF[d]	Backup Heat Type	Weather-Normalized Heating kWh Consumption of Condenser + Fan (backup heat not included)
EY1						
1-1	BGE	3	15	8.5	ER	5,290
1-3	BGE	3	15	10	ER	315
1-8	BGE	3	18.2	9.5	ER	2,818
1-9	BGE	5	16	9.5	ER	1,550
1-10	BGE	3	15	8.75	ER	2,285
1-16	BGE	2	15	8.5	ER	3,511
1-17	BGE	2.5	15.75	8.5	ER	4,867
1-18	BGE	3	17.8	9.2	ER	440
1-19	BGE	2.5	15	9.25	ER	3,513
1-20	BGE	2	15.25	8.6	ER	4,333
1-21	BGE	2.5	15	9	Oil	3,557
1-27	BGE	2.5	15.5	8.5	None	3,429
1-28	BGE	1.5	15	8.5	ER	2,711
1-New Site	BGE	2.5	14.5	8.8	ER	1,704
EY4						
4-26	Pepco	2.0	16.0	8.9	ER	3,400
4-27	Pepco	2.0	15.0	8.5	ER	1,564
4-29	Pepco	1.5	15.0	8.75	Gas	511
4-30	SMECO	3.0	15.0	8.5	ER	2,954
4-31	SMECO	2.0	15.0	8.5	ER	1,390
4-32	SMECO	2.5	15.0	8.5	ER	4,005
4-33	PE	1.5	15.0	8.75	ER	1,740
4-34	PE	3.0	16.0	8.9	Gas	475
4-35	SMECO	4.0	17.0	9	ER	2,391

Site #[a]	Utility[b]	Tons	SEER[c]	HSPF[d]	Backup Heat Type	Weather-Normalized Heating kWh Consumption of Condenser + Fan (backup heat not included)
4-36	SMECO	2.5	16.0	9.5	ER	3,695
4-37	SMECO	1.0	21.0	10	ER	4,170
4-38	SMECO	3.0	15.0	8.5	ER	1,560
4-39	PE	3.0	17.0	9	ER	930
4-40	SMECO	3.0	18.5	9.25	ER	5,878
4-41	SMECO	3.0	15.5	9	Gas	573
4-42	SMECO	3.0	16.0	9	ER	3,422
Average		**2.6**	**15.9**	**8.9**		**2,632.7**

Note: Some HSPF values missing because they were not reported by the utility and because field staff members were unable to confirm AHRI-rated HSPF value.

To assess energy consumption and savings, the team used PJM's Option A, which corresponds with Option A of the IPMVP manual: "Partially Measured Retrofit Isolation/Stipulated Measurement." Using the PJM option as a guide, the team performed the following evaluation activities, using measurement and verification methods compliant with PJM Manual 18B:

» Spot-measured and logged the true power for a random sa at a two-minute interval (consumption, demand, and hour measurement). Figure 5 and Figure 6 show the condenser e transformer (CT) used to meter fan current and power.
» Using solar-shielded sensors, logged outdoor temperatures in the vicinity of condensers.
» Spot-measured the true power, volts, amps, and power factor of indoor fans.
» Logged fan currents and the backup electric resistance heater plate current of heat pumps at two minute intervals.
» Logged indoor and outdoor temperature and relative humidity at two-minute intervals.

Figure 5. Condenser Energy Logger

Figure 6. Current Transformer

To verify the logger accuracy, the evaluation team took spot power and temperature measurements in the field for all of the logging input parameters. Table 27 provides information about the instrumentation used to measure the energy consumption of the HVAC units, the indoor and outdoor temperatures, and the relative humidity.

Table 27. Metering Instrumentation

Function/ Data Point to Measure	Equipment Brand/ Model	Quantity	Rated Full Scale Accuracy		Accuracy of Expected Measurement		Metering Duration	Planned Metering Interval
Energy/time	Wattnode/WNB-3Y-240-P	1	±0.05%		±0.45%		4 - 9 months	2 min
Outdoor Ambient Temperature/ RH%	Hobo Microstation with S-TMB-M002 Sensor	1	±0.36°F	±3.5% RH	±0.3°F	±3.0% RH	4 - 9 months	2 min
Indoor Temperature/ RH%	Hobo Temp/RH logger	1	±0.36°F	±3.5% RH	±0.3°F	±3.0% RH	4 - 9 months	5 min
Fan Current and Electric Resistance (Heat Pump)	50 A CT	2	± 1%		± 1%		4 - 9 months	2 min

Source: Onset Computers

E.5.3. ASHP Analysis

The team used the metered data with specific equipment data provided by the manufacturer of each heat pump metered. Section E.5.1 describes the meter data analysis.

The team adjusted the meter data results to account for weather differences from the metered period to a typical weather year and to account for weather differences between the metered sites and the population of participants for each utility. This adjustment is described below.

Seasonal Weather Adjustment

The evaluation team used a seasonal weather adjustment to normalize weather during the EY3 metering period to a normal weather year. Energy consumption and savings could then be adjusted for the 16 metered sites by the ratio of normal heating degree days (HDDs) (base 65), drawn from the weather station nearest to each site, to the typical meteorological year (TMY) 30 HDD normal for that weather station. The calculation required a 2.5% downward adjustment as 2012–2013 experienced a cooler-than-normal winter.

After normalizing EY1 and EY4 meter data to TMY30, the evaluation team combined the weather normalized observations of the two studies.[26]

Adjusting Normalized Results to Measure-Weighted Utility HDD

To account for measure saturation across different climates, the evaluation team used ZIP codes to map the reported measures from each utility tracking database to the closest weather station. This information helped the team develop a weighted HDD value for each utility. Table 28 provides the utility-specific, weighted HDDs for a typical weather year. The weighted HDDs are used to adjust the heating EFLH values reported below in Table 30.

Table 28. Measure-Weighted Average HDD by Utility

Utility	Measure-Weighted Average HDD
BGE	4,563
Pepco	4,728
DPL	4,196
PE	4,739
SMECO	4,366

Modeling Energy Consumption and Savings for Periods not Metered

For the EY3 metering study, Cadmus metered ASHPs from late July 2012 through April 2013 to monitor ASHP performance during both the cooling and heating seasons. Although this period included most of the heating season, the evaluation team anticipated some ASHP heating operation during May. Air-source heat pumps operate similarly in May and October; therefore, the evaluation team assumed that these months were similar in terms of their relative use of backup heat. For each site, the team used the October daily energy use per HDD and daily May HDD values to estimate energy use and savings for May 2013, which was not metered.

Three of the 16 EY3 metered sites captured only about one-half of the winter HDD. To account for the missing data, the evaluation team reviewed each data file and used the site-specific correlation between energy consumption and HDD to develop a daily HDD-to-kWh relationship. The team used these regressions to estimate energy consumption at these three sites for the periods not metered.

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[26] TMY30 is the average "typical meteorological year" data captured over the past 30 years.

E.5.4. ASHP Findings

Table 29 shows energy savings calculated from the combined EY1 and EY3 ASHP metering studies. The EY1 study estimated normalized BGE savings at 184 kWh/ton. The combined studies of all utilities estimated the normalized savings at 194 kWh/ton.

Table 29. ASHP Heating Energy Savings

Site #	Utility	System Size (Tons)	Metered kWh (Fan + Condenser)	kWh Saved (Per Ton)
1-1	BGE	3	5,290	169
1-3	BGE	3	315	172
1-8	BGE	3	2,818	313
1-9	BGE	5	1,550	258
1-10	BGE	3	2,285	279
1-16	BGE	2	3,511	163
1-17	BGE	2.5	4,867	233
1-18	BGE	3	440	285
1-19	BGE	2.5	3,513	173
1-20	BGE	2	4,333	194
1-21	BGE	2.5	3,557	145
1-27	BGE	2.5	3,429	4
1-28	BGE	1.5	2,711	41
1-New Site	BGE	2.5	1,704	148
4-26	Pepco	2.0	3,400	229
4-27	Pepco	2.0	1,564	76
4-29	Pepco	1.5	511	44
4-30	SMECO	3.0	2,954	163
4-31	SMECO	2.0	1,390	106
4-32	SMECO	2.5	4,005	208
4-33	PE	1.5	1,740	115
4-34	PE	3.0	475	30
4-35	SMECO	4.0	2,391	131
4-36	SMECO	2.5	3,695	251

Site #	Utility	System Size (Tons)	Metered kWh (Fan + Condenser)	kWh Saved (Per Ton)
4-37	SMECO	1.0	4,170	879
4-38	SMECO	3.0	1,560	77
4-39	PE	3.0	930	49
4-40	SMECO	3.0	5,878	621
4-41	SMECO	3.0	573	27
4-42	SMECO	3.0	3,422	235
Average		**2.6**	**2,634**	**194**

*The site used alternate backup heat (and did not use ER).

Using 194 kWh metered savings per ton, the evaluation team back-calculated the TRM algorithm to determine the heating EFLH value for each utility, as shown in Table 30. This is the same process used to determine the "metered adjustment factor" provided in previous evaluation reports. The table also includes cooling EFLH values from the EY3 Residential HVAC impact evaluation report.[27] For simplicity, the team omits this metered adjustment factor and reports only the utility-specific EFLH, which should be used with the TRM algorithm. These values, which are adjusted by the measure-weighted HDD in Table 28, use the participation data from EY3 and EY4.

Table 30. Heating and Cooling EFLH Values from the EY3-EY4 Metering Study

Utility	ASHP: Cooling* EFLH	ASHP: Heating EFLH (EY4/EY3**)	CAC: Cooling* EFLH
BGE	778	852/896	568
Pepco	717	883/932	523
DPL	739	784/825	539
PE	712	885/932	515
SMECO	775	815/860	565

Source: Cadmus analysis
*No change in EY4
**EY3 ASHP EFLH values are included for comparison

[27] EmPOWER Maryland 2012 Final Evaluation Report Residential HVAC Program, March 1, 2013

The evaluation team recommends that EmPOWER utilities use the utility-specific EFLH values in Table 30 and the algorithm below to estimate ASHP savings.

The modified Mid-Atlantic TRM ex post savings calculation for ASHPs is:[28]

$$\Delta kWh = EFLH_C \times \frac{BTU_c}{1000} \times \left(\frac{1}{13} - \frac{1}{SEER_{ee}}\right) + EFLH_H \times \frac{BTU_h}{1000} \times \left(\frac{1}{7.7} - \frac{1}{HSPF_{ee}}\right)$$

Where:

$EFLH_C$	= Equivalent full load hours for cooling
BTU_c	= Rated cooling capacity
13	= Seasonal energy efficiency ratio for baseline ASHP
$SEER_{ee}$	= Seasonal energy efficiency ratio for installed ASHP
$EFLH_H$	= Equivalent full load hours for heating
BTU_h	= Rated heating capacity
7.7	= Heating season performance factor for baseline ASHP
$HSPF_{ee}$	= Heating season performance factor for installed ASHP

Additional Findings

During analysis of the ASHP metering study, the evaluation team observed differences in the performance of ASHP systems with electric resistance or gas furnace backup heating. The team also noted that for several units with electric resistance backup, the electric resistance heat operated more hours than expected. Although the evaluation was not designed to distinguish savings differences for these different system types, it is important to consider the potential decrease in savings if gas furnace backup or ER-control issues become more prevalent among program participants.

Table 31 compares the nameplate-rated HSPF to field-metered HSPF in EY1 and EY4. Four of 16 systems metered in EY4 appeared to use more electric resistance than necessary (noted in comments in Table 31), and 3 of 16 systems metered in EY4 use a gas furnace for backup heating.

Table 31. Nominal and Metered HSPF (EY3 Sites)

Site #	Nameplate HSPF	Field HSPF*	Comments
1-1	8.5	8.2	

[28] The Mid-Atlantic TRM first provided an algorithm for ASHP savings in V2.0, which did not become available until July 2011. Version 3.0 maintains the calculation provided in V2.0.

Site #	Nameplate HSPF	Field HSPF*	Comments
1-3	10	8.4	
1-8	9.5	7	
1-9	9.5	6.1	
1-10	8.75	8.6	
1-16	8.5	6.8	
1-17	8.5	8.3	
1-18	9.2	9.3	
1-19	9.25	5.5	Data indicate that ASHP did not run after beginning of February 2011, but electric resistance did run.
1-20	8.6	9.8	
1-21	9	11.6	An oil furnace was used to heat the home at this site. Because of the configuration of the furnace, fan power was not metered.
1-27	8.5	3.5	Very little energy consumption at this home because additional heat sources were used.
1-28	8.5	8.8	This townhouse often averaged a 54°F indoor temperature. The homeowner reported it was vacant for a portion of winter.
1-New Site	8.8	7.7	
4-26	9.3	10.8	High coincidence at 30°F.
4-27	8.8	5.4	Data suggest ASHP control issues, due to high electric resistance use.
4-29	8.9	10.5	Has gas furnace.
4-30	8.8	8.9	
4-31	9.0	8.9	
4-32	8.5	9.1	
4-33	8.5	6.2	Data suggest ASHP control issues, due to high electric resistance use.
4-34	9.0	12.9	Has gas furnace.
4-35	9.0	8.1	
4-36	9.5	9.1	

Site #	Nameplate HSPF	Field HSPF*	Comments
4-37	10.0	8.7	More electric resistance use than is necessary.
4-38	9.0	8.5	
4-39	9.5	4.5	Data suggest ASHP control issues, due to high electric resistance use.
4-40	9.8	10.8	High coincidence at 30°F.
4-41	9.0	10.7	Has gas furnace.
4-42	9.0	9.1	
Mean	**9.1**	**8.9**	

* Field HSPF is the ratio of rated heating capacity to the metered total heating energy consumption.

Electric Resistance Heat Control. The evaluation team assumed similar use of electric resistance heating for baseline and new units, so electric resistance backup heat use did not directly affect calculated energy savings. However, the evaluation team observed several systems with extensive electric resistance operation. Electric resistance heating is less efficient than ASHPs for most temperatures and typically operates only during very cold temperatures. Improper electric resistance installation and control can result in high consumption and a low HSPF, regardless of the unit's nominal efficiency.[29]

ASHP with Gas Furnace backup. Systems with backup gas furnaces exhibited high field-measured HSPF values but achieved lower-than-average energy savings. The high HSPF values for the ASHP reflect the inability of the ASHP and gas furnaces to run simultaneously, resulting in reduced ASHP operation compared to systems with electric resistance backup heat.

E.6. Utility-Specific Findings

The utilities are correctly using the recommended algorithms and inputs to estimate savings for most measures. This section discusses the reasons for any differences between ex ante reported savings and ex post evaluated savings.

E.6.1. BGE Measure-Level Savings

Table 32 lists BGE's ex ante and ex post evaluated savings by measure category.

[29] Proper control maximizes the heat capacity provided by the heat pump condenser, only allowing the electric resistance backup heat to run when absolutely necessary.

Table 32. BGE Ex Ante and Evaluated Gross by Measure Category

Metric	Measure Category	Ex Ante Tracked Gross Savings*	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	ASHP	1,140	1,508	1.32
	Central AC	1,417	1,428	1.01
Utility Coincident Peak Demand Savings (kW)	ASHP	1,190	1,370	1.15
	Central AC	1,478	1,273	0.86
	Duct Sealing	7	7	1.00
	Furnace	34	0	0
	GSHP	419	259	0.62
	Mini Split AC	4	3	0.76
	Mini Split HP	22	18	0.85
	Tune-up	8	2	0.20
Annual Energy Savings (MWh)	ASHP	4,617	3,832	0.83
	Central AC	1,692	1,347	0.80
	Duct Sealing	6	6	1.00
	Furnace	477	477	1.00
	GSHP	1,219	611	0.50
	Mini Split AC	8	7	0.78
	Mini Split HP	108	92	0.86
	Tune-up	2	2	0.94

* Tracked savings reflects program tracking database values.

** PJM savings are only tracked for measures that the utility bids into the forward capacity market.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

The differences in savings are reduced from previous years as BGE continues to adopt evaluation data to estimate savings. The following list describes reasons for the differences between BGE's ex ante reported values and ex post evaluated savings values.

» The evaluated energy savings for ASHPs is 83% of the tracked energy savings. ASHP heating EFLH were updated to reflect the metering results from the 2013 metering study. The evaluation team used 778 cooling EFLH and 852 heating EFLH with tons, SEER, and HSPF to estimate savings for each measure reported.

- The evaluated energy savings for CACs is 80% of the tracked energy savings. The reduction in energy savings is due to a reduction in the cooling EFLH for CACs. The evaluation team updated the value of 715 EFLH to 568 EFLH, based on results of the EY3 metering study.
- The evaluation team changed the ground-source baseline from a federal minimum efficiency ASHP to an ENERGY STAR Tier 1 ground-source heat pump. This change resulted in an energy realized savings ratio of 50%.
- Ex ante tune-up savings are the same for both CACs and ASHPs. Ex post tune-up savings were estimated using contractor's reported measurements.

E.6.2. Pepco Measure-Level Savings

Table 33 lists Pepco's ex ante and ex post evaluated savings by measure category.

Table 33. Pepco Ex Ante and Evaluated Gross by Measure Category

Metric	Measure Category	Ex Ante Tracked Gross Savings*	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	ASHP	267	373	1.40
	Central AC	721	758	1.05
Utility Coincident Peak Demand Savings (kW)	ASHP	279	337	1.21
	Central AC	754	665	0.88
	Duct Sealing	20	20	1.00
	GSHP	41	26	0.63
	Mini Split HP	4	3	0.82
	Tune-up	201	40	0.20
Annual Energy Savings (MWh)	ASHP	1,002	872	0.87
	Central AC	792	619	0.78
	Duct Sealing	18	18	1.00
	GSHP	112	60	0.54
	Mini Split HP	16	14	0.89
	Tune-up	81	31	0.38

* Tracked savings reflects program tracking database values.
** PJM savings are only tracked for measures that the utility bids into the forward capacity market.
Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

The differences in savings are reduced from previous years as Pepco has adopted the evaluation data and evaluation methodology to estimate savings for all measures as recommended in the EY3 report. The following list describes reasons for the differences in Pepco's ex ante reported values and ex post evaluated savings values.

» The evaluated energy savings for ASHP is 87% of the tracked energy savings. The ASHP heating EFLH were updated to reflect the metering results from the 2013 metering study. The evaluation team used 717 cooling EFLH and 883 heating EFLH with tons, SEER, and HSPF to estimate savings for each measure reported.

» The evaluated energy savings for CAC is 78% of the tracked energy savings. Pepco is not using the evaluated value of 523 EFLH for CACs with reported SEER and tons to estimate savings.
» The evaluation team changed the ground source baseline from a federal minimum efficiency ASHP to an ENERGY STAR Tier 1 GSHP. This change resulted in an energy realized savings ratio of 54%.
» Ex ante tune-up savings are the same for both ASHPs and CACs (deemed 200 kWh and 0.5 kW). Zero savings were reported for approximately 5% of measures. Ex post tune-up savings were estimated using contractor's reported measurements for each tune-up reported.

E.6.3. DPL Measure-Level Savings

Table 34 lists DPL's ex ante and ex post evaluated savings by measure category.

Table 34. DPL Ex Ante and Evaluated Gross by Measure Category

Metric	Measure Category	Ex Ante Tracked Gross Savings*	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	ASHP	89	118	1.32
	Central AC	31	31	1.00
Utility Coincident Peak Demand Savings (kW)	ASHP	93	107	1.15
	Central AC	32	28	0.86
	Duct Sealing	0	0	0.00
	GSHP	59	35	0.60
	Mini Split HP	1	1	0.90
	Tune-up	20	8	0.41
Annual Energy Savings (MWh)	ASHP	355	297	0.84
	Central AC	27	28	1.02
	Duct Sealing	0	0	0.00
	GSHP	157	77	0.49
	Mini Split HP	6	5	0.90
	Tune-up	6	17	2.76

* Tracked savings reflects program tracking database values.

** PJM savings are only tracked for measures that the utility bids into the forward capacity market.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

The differences in savings are reduced from previous years as DPL has adopted the evaluation data and evaluation methodology to estimate savings for all measures as recommended in the EY3 report. The following list describes reasons for the differences in DPL's ex ante reported values and ex post evaluated savings values.

- The evaluated energy savings for ASHP is 84% of the tracked energy savings. The ASHP heating EFLH were updated to reflect the metering results from the 2013 metering study. The evaluation team used 739 cooling EFLH and 784 heating EFLH with tons, SEER, and HSPF to estimate savings for each measure reported.
- The evaluation team changed the ground source baseline from a federal minimum efficiency ASHP to an ENERGY STAR Tier 1 GSHP. This change resulted in an energy realized savings ratio of 49%.
- The evaluated energy savings for tune-up measures is almost three times the tracked energy savings. Ex ante tune-up savings are the same for both CACs and ASHPs, not accounting for heat pump heating savings. Ex post tune-up savings were estimated using contractor's reported measurements.

E.6.4. PE Measure-Level Savings

Table 35 lists PE's ex ante and ex post evaluated savings by measure category.

Table 35. PE Ex Ante and Evaluated Gross by Measure Category

Metric	Measure Category	Ex Ante Tracked Gross Savings*	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	ASHP	224	257	1.15
	Central AC	110	114	1.04
Utility Coincident Peak Demand Savings (kW)	ASHP	224	237	1.06
	Central AC	110	109	1.00
	GSHP	10	26	2.52
	Mini Split AC	2	0	0.27
	Mini Split HP	0	6	0.00
	Tune-up	55	342	6.26
Annual Energy Savings (MWh)	ASHP	817	734	0.90
	Central AC	102	110	1.07
	GSHP	49	60	1.23
	Mini Split AC	0	1	3.41
	Mini Split HP	0	35	0.00
	Tune-up	128	669	5.21

* Tracked savings reflects program tracking database values.

** PJM savings are only tracked for measures that the utility bids into the forward capacity market.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

PE savings are mostly attributable to tune-ups, ASHP, and CAC measures. The realized savings ratios are not 100% for several reasons:

- The ASHP heating EFLH were updated to reflect the metering results from the 2013 metering study. The evaluation team used 712 cooling EFLH and 885 heating EFLH with tons, SEER, and HSPF to estimate savings for each measure reported.
- The evaluated energy savings for CACs was equal to the tracked energy savings even though savings are calculated differently. PE appears to use deemed savings estimates for two efficiency tiers of CACs. The evaluation used the TRM algorithms with EFLH values specific to PE weather.

- The evaluated energy savings for Tune-up measures about five times the tracked energy savings. PE assumed only 32 kWh per measure. The evaluation used specific information about work performed on tune-ups, including refrigerant charge adjustment and coil cleaning.
- The evaluation team changed the ground source baseline from a federal minimum efficiency ASHP to an ENERGY STAR Tier 1 GSHP.

E.6.5. SMECO Measure-Level Savings

Table 36 lists SMECO's ex ante and ex post evaluated savings by measure category.

Table 36. SMECO Ex Ante and Evaluated Gross by Measure Category

Metric	Measure Category	Ex Ante Tracked Gross Savings*	Ex Post Evaluated Gross Savings	Gross Realized Savings Ratio
PJM Coincident Peak Demand Savings (kW)**	ASHP	248	363	1.47
	Central AC	34	39	1.16
Utility Coincident Peak Demand Savings (kW)	ASHP	273	328	1.20
	Central AC	36	35	0.96
	GSHP	78	51	0.65
	Mini Split HP	5	4	0.81
	Tune-up	22	4	0.20
Annual Energy Savings (MWh)	ASHP	986	840	0.85
	Central AC	41	33	0.80
	GSHP	243	118	0.48
	Mini Split HP	25	21	0.85
	Tune-up	9	10	1.20

* Tracked savings reflects program tracking database values.

** PJM savings are only tracked for measures that the utility bids into the forward capacity market.

Sources: Utility tracking data (unadjusted gross savings) and Cadmus analysis

Note: Values reported in the table are rounded.

The differences in savings are reduced from previous years as SMECO has adopted the evaluation data and evaluation methodology to estimate savings for all measures as recommended in the EY3 report. The following list describes reasons for the differences in SMECO's ex ante reported values and ex post evaluated savings values.

- The evaluated energy savings for ASHP is 85% of the tracked energy savings. The ASHP heating EFLH were updated to reflect the metering results from the 2013 metering study. The evaluation team used 775 cooling EFLH and 815 heating EFLH with tons, SEER, and HSPF to estimate savings for each measure reported.
- The evaluated energy savings for CAC is 80% of the tracked energy savings. SMECO uses 715 EFLH to estimate savings for CACs while the evaluation team used the EY3 value of 565 EFLH.
- The evaluation team changed the ground source baseline from a federal minimum efficiency ASHP to an ENERGY STAR Tier 1 GSHP. This change resulted in an energy realized savings ratio of 48%.
- Ex ante tune-up savings are the same for both CACs and ASHPs. Ex post tune-up savings were estimated assuming a tune-up saves 3.7% energy and demand. SMECO's tune-up data sheets do not provide information about the specific work performed to approve HVAC unit efficiency so the team used the average savings of a tune-up from all other utilities.

Appendix F: Statistical Significance of Gross Impacts

For EY3, the evaluation team calculated the standard error of all heat pump and central air conditioners (CAC) meter data collected in 2010 and 2012, normalizing by seasonal differences between 2010 and 2012. For cooling, the evaluation team reported uncertainty in EY3.

For heat pump heating savings, the team used meter data to calculate savings directly, and then back-calculated an EFLH value for heat pump heating from the savings value (described in section E.5.4). The tables below show the statistical uncertainty around the energy-savings estimate, normalized by ton. Table 37 shows calculated metering savings and the upper/lower confidence interval for the EY1 evaluation from ASHPs only studied in BGE's territory. The relative precision of this estimate is +/- 16% with a 90% one-tailed confidence interval.

Table 37. ASHP Energy Savings Confidence for EY1 (BGE Sample Only)

CV for Metered Energy Savings*	Average Metered Savings (kWh/ton)	Upper Limit (kWh/ton)	Lower Limit (kWh/ton)	Relative Precision
0.48	184	214	154	0.16

*CV = Coefficient of Variance
Source: Cadmus analysis

Table 38 shows calculated metered savings as well as the upper/lower confidence interval for the EY3 metering evaluation drawn from ASHPs studied in all other EmPOWER utility service territories. The CV is significantly higher due to energy consumption varying more among EY3 metering study sites than among those metered during EY1. Several sites indicated low energy consumption and savings as gas furnaces provided most of the heat (as noted in Table 31). The relative precision of this estimate is +/- 36% with a 90% one-tailed confidence interval.

Table 38. ASHP Heating Energy Savings Confidence for EY3 (All Other Utilities)

CV for Metered Energy Savings	Average Metered Savings (kWh/ton)	Upper Limit (kWh/ton)	Lower Limit (kWh/ton)	Relative Precision
1.14	203	277	129	0.36

Source: Cadmus analysis

Table 39 shows the combined savings from ASHPs metered in BGE's territory during EY1, with ASHPs metered in the remaining utilities during EY3. Combining all meter data resulted in 21% relative precision with a 90% one-tailed confidence interval.

Table 39. ASHP Heating Energy Savings Confidence for Combined Metering Studies (EY1 + EY3)

CV for Metered Energy Savings	Average Metered Savings (kWh/ton)	Upper Limit (kWh/ton)	Lower Limit (kWh/ton)	Relative Precision
0.91	194	235	153	0.21

Source: Cadmus analysis

Table 40 through Table 54 show overall uncertainty at the program level due to sampling.

Table 40. BGE PJM Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
PJM Coincident Peak Demand Savings (kW)	2,936	215	0.10
Gross Realized Savings Ratio	1.15	0.08	0.10

*Based on 90% one-sided confidence interval

Table 41. BGE Utility Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
Utility Coincident Peak Demand Savings (kW)	2,932	212	0.09
Gross Realized Savings Ratio	0.94	0.07	0.09

*Based on 90% one-sided confidence interval

Table 42. BGE Energy Statistical Precision

	Value	Standard Error*	Relative Precision
Energy Savings (MWh)	6,373	430	0.09
Gross Realized Savings Ratio	0.78	0.05	0.09

*Based on 90% one-sided confidence interval

Table 43. Pepco PJM Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
PJM Coincident Peak Demand Savings (kW)	1,132	88	0.10
Gross Realized Savings Ratio	1.15	0.09	0.10

*Based on 90% one-sided confidence interval

Table 44. Pepco Utility Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
Utility Coincident Peak Demand Savings (kW)	1,092	90	0.11
Gross Realized Savings Ratio	0.84	0.07	0.11

*Based on 90% one-sided confidence interval

Table 45. Pepco Energy Statistical Precision

	Value	Standard Error*	Relative Precision
Energy Savings (MWh)	1,614	110	0.09
Gross Realized Savings Ratio	0.80	0.05	0.09

*Based on 90% one-sided confidence interval

Table 46. DPL PJM Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
PJM Coincident Peak Demand Savings (kW)	149	13	0.11
Gross Realized Savings Ratio	1.24	0.10	0.11

*Based on 90% one-sided confidence interval

Table 47. DPL Utility Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
Utility Coincident Peak Demand Savings (kW)	179	12	0.09
Gross Realized Savings Ratio	0.87	0.06	0.09

*Based on 90% one-sided confidence interval

Table 48. DPL Energy Statistical Precision

	Value	Standard Error*	Relative Precision
Energy Savings (MWh)	424	32	0.10
Gross Realized Savings Ratio	0.77	0.06	0.10

*Based on 90% one-sided confidence interval

Table 49. Potomac Edison PJM Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
PJM Coincident Peak Demand Savings (kW)	371	29	0.10

Gross Realized Savings Ratio	1.11	0.09	0.10

*Based on 90% one-sided confidence interval

Table 50. Potomac Edison Utility Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
Utility Coincident Peak Demand Savings (kW)	721	29	0.05
Gross Realized Savings Ratio	1.80	0.07	0.05

*Based on 90% one-sided confidence interval

Table 51. Potomac Edison Energy Statistical Precision

	Value	Standard Error*	Relative Precision
Energy Savings (MWh)	1,609	80	0.06
Gross Realized Savings Ratio	1.47	0.07	0.06

*Based on 90% one-sided confidence interval

Table 52. SMECO PJM Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
PJM Coincident Peak Demand Savings (kW)	403	37	0.12
Gross Realized Savings Ratio	1.43	0.13	0.12

*Based on 90% one-sided confidence interval

Table 53. SMECO Utility Coincident Peak Demand Statistical Precision

	Value	Standard Error*	Relative Precision
Utility Coincident Peak Demand Savings (kW)	422	35	0.11
Gross Realized Savings Ratio	1.02	0.08	0.11

*Based on 90% one-sided confidence interval

Table 54. SMECO Energy Statistical Precision

	Value	Standard Error*	Relative Precision
Energy Savings (MWh)	1,022	90	0.12
Gross Realized Savings Ratio	0.78	0.07	0.12

*Based on 90% one-sided confidence interval

Appendix G: Net Impact Evaluation

This appendix provides a detailed look at the evaluation team's net impact evaluation. It describes data collection techniques, data analysis, findings, and the statistical significance of the net results.

G.1. Data Collection

The residential HVAC impact evaluation plan called for analyzing the combined results of a standard market practice study and a participant phone survey to determine the program's net-to-gross (NTG) rate.

G.1.1. Standard Market Practice Study

The evaluation team reached out to 26 distributors serving HVAC contractors in Maryland:

» 2 contacts provided by Honeywell (implementer for PE)
» 10 provided by ICF (the implementer for BGE, SMECO, and PHI)
» 14 non-participating distributors (branches and headquarters) identified through Web searches for HVAC distributors

Based on interest generated for this study in EY3, the team's goal was to obtain sales data from five distributors. In the end, six distributors that partner with the utilities agreed to participate in the study and five provided data in time for analysis. Results are summarized in Table 55.

Table 55. Distributor Outreach Results

	Total Number	No Response	Declined to Participate	Agreed to Participate, but did not Provide Data	Agreed to Participate and Provided Data
Distributors Partnering with a Utility	12	1	5	1	5
Non-Participating Distributors	14	4	10	0	0
Total Distributors	26	5	15	1	5

For each distributor, Cadmus made at least four attempts to talk with a decision maker.

- Of the 14 distributors who were not partnering with a utility, ten (71%) declined to participate in the study and the remaining four (29%) did not respond to Cadmus' calls.
- Of the 12 distributors partnering with a utility, six (50%) agreed to participate in the study, but only 5 (42%) provided sales data. The remaining six (50%) were unresponsive or declined to participate.

G.1.2. Participant Survey

To obtain data for analyses of freeridership and spillover for the EmPOWER HVAC program, the evaluation team conducted telephone surveys with participating customers regarding their purchase decisions. (See questions C1–C9 and D1-3 in the customer survey instrument, found in Appendix H, page 87.)

The evaluation team surveyed 101 customers who participated in the Residential HVAC program between October 1, 2012, and May 31, 2013: 25 each from BGE, PE, and SMECO territories, 13 each from Pepco and DPL. The team created a random sample from each utility's tracking data that assured appropriate representation. Pacific Market Research fielded the phone survey from late September through early October 2013. The team used a combination of EY4 and EY3 participant survey data to estimate freeridership for EY4. 101 survey respondents were surveyed in 2013 and 72 survey respondents were surveyed in 2012 (EY3).

G.2. Analysis

G.2.1. Standard Market Practice Study

Five distributors provided sales data—including SEER and quantity—for CAC and ASHP condensers sold to Maryland contractors between July 1, 2012, and June 30, 2013.[30] The evaluation team merged the distributors' data to determine how sales were allocated across SEER levels.

However, the SEER of a CAC or ASHP system depends not only on the condenser but also on the type of fan motor that the air handler uses. Typically, an ECM will increase the operating SEER of a condenser by one SEER level—that is, an ECM will generally make a 14 SEER condenser operate as a 15 SEER system. Therefore, the evaluation team collected qualitative feedback on ECM installation practices from Maryland contractors. During the participating and non-participating contractor focus groups conducted as part of the Residential HVAC

[30] Because distributors typically report data on a quarterly basis, the evaluation team collected data for the quarters nearest to the evaluation period (June 2012 – May 2013).

process evaluation, contractors answered questions about the percent of CACs and ASHPs they install with ECMs at various SEER levels.[31] Contractor responses are summarized in Table 56.

Table 56. Estimated Percent of CACs and ASHPs Installed with ECMs

System Efficiency	% of Equipment Installed with an ECM
SEER 13	0%
SEER 14	75%
SEER 16	100%

Source: Cadmus analysis

The evaluation team applied the ECM installations rates from Table 56 to the distributor condenser sales data to estimate the number of CAC and ASHP *system* installations. Table 57 and Table 58 provide a summary of condenser sales from distributors and an ECM allocation.

Table 57. Allocation of CAC Condensers and Systems by SEER

	Condenser Allocation (from Distributors)	System Allocation (with ECM Adjustment)
<13 SEER	5%	5%
13 SEER	67%	67%
14 SEER	11%	8%*
15 SEER	10%	10%**
16 SEER	2%	3%***
>16 SEER	5%	7%

* ECM-adjusted SEER 14 = 75% of SEER 14 sales data

** ECM-adjusted SEER 15 = 25% of SEER 14 sales data + 75% of SEER 15 sales data

*** ECM-adjusted SEER 16 = 25% of SEER 15 sales data +75% of SEER 16 sales data

Source: Cadmus analysis

[31] See the Residential HVAC Process Evaluation Memo, draft dated March 28, 2014, for additional details on the contractor focus groups.

Table 58. Allocation of ASHP Condensers and Systems by SEER

	Condenser Allocation (from Distributors)	System Allocation (with ECM Adjustment)
<13 SEER	0%	0%
13 SEER	63%	63%
14 SEER	14%	11%
15 SEER	10%	11%
16 SEER	9%	3%
>16 SEER	3%	12%

Source: Cadmus analysis

Percent of Market Represented by Distributor Data

Next, the team estimated the annual number of CAC and ASHP sales in Maryland to determine how much of the market the distributor-provided sales data covered. The team used data collected in 2012 from the American Community Survey[32] and American Housing Survey[33] to estimate the total number of CACs and ASHPs in Maryland homes. The 2011 census data showed that of the 2,128,377 occupied homes in Maryland, 72.4% (1,540,934 households) have a CAC or ASHP for cooling.

The Mid-Atlantic TRM Version 3.0 uses a measure life of 18 years for CACs and ASHPs. This suggests that one in 18 units is likely to be replaced each year, or an annual replacement rate of 5.56% (1/18). To determine total number of annual replacements each year, the team used the following equation:

Number of Homes with CAC or ASHP x Annual Replacement Rate = Number of Annual Replacements

1,540,934 x 5.56% = 85,607 Estimated Units Replaced Each Year

This suggests that the sales data collected from the five distributors represent about 36% of the total estimated units replaced each year. By comparison, the distributor data collected by the evaluation team in 2012 represented about 13% of the estimated units replaced each year.

[32] U.S. Census Bureau, 2007-2011 American Community Survey

[33] U.S. Census Bureau, 2007 American Housing Survey

Percent of High-Efficiency Sales Represented by EmPOWER Programs

Finally, the evaluation team estimated the percent of high-efficiency sales that go through the EmPOWER Residential HVAC programs. Energy Information Administration (EIA) Form 861 data shows that EmPOWER utilities have a combined total of 1,788,812 residential customers, which means they represent 84% of the total occupied homes in Maryland (2,128,377 total occupied units / 1,788,812 EmPOWER utilities residential customers).

The team first divided the ECM-adjusted high-efficiency sales data by 36% to calculate the total number of high-efficiency CAC and ASHP condensers sold in Maryland.[34]

Next, the team multiplied total number of high-efficiency systems sold in Maryland by 84% to determine the number of high-efficiency systems sold in EmPOWER utilities' territories.

The combined results of these steps allowed the team to calculate the percent of high-efficiency systems purchased each year that were paid by the EmPOWER programs. The formula to calculate this is:

> *Number of high-efficiency rebates in tracking data*[35] */*
>
> *Adjusted number of high-efficiency sales in EmPOWER territory each year =*
>
> *Percent of high-efficiency sales in EmPOWER territory that were paid by the programs*

Table 59 and Table 60 show that the EmPOWER Residential HVAC programs paid rebates for approximately 82% of the total high-efficiency CAC and ASHP installations in the EmPOWER utilities territory. Tracking data for 16+ SEER CACs and 15 SEER ASHPs exceed the team's estimate of total sales in the EmPOWER utilities' territories. This clearly indicates that there are errors in our market estimations; however, it provides a good indication that utilities are paying rebates for a significant portion of these units.

Table 59. Percent of EmPOWER Territory High-Efficiency CAC Sales Paid by the Residential HVAC Programs

SEER	Q3 2012 - Q2 2013 Adjusted Sales Data (EmPOWER	Q3 2012 - Q2 2013 Tracking	Tracking Data % of Sales

[34] While the EmPOWER Residential HVAC program rebates begin at 14.5 SEER, distributors provided data in whole SEER levels. For the purpose of this analysis, the evaluation team considers "high efficiency" to mean 15 SEER or greater.

[35] To ensure comparison of similar periods, the evaluation team used program tracking data from July 1, 2012 to June 30, 2013 for this analysis.

	Territory Only)*	Data	Data
15 SEER	4,115	1,085	26%
16+ SEER	3,980	5,518	139%
Total	8,095	6,603	82%

Source: Cadmus analysis

* ECM-adjusted distributor sales data / 36% (estimated percent of Maryland HVAC market covered by the distributor sales data) x 84% (estimated percent of Maryland residential customers who are a customer of an EmPOWER utility)

Table 60. Percent of EmPOWER Territory High-Efficiency ASHP Sales Paid by the Residential HVAC Programs

SEER	Q3 2012 - Q2 2013 Sales Data (EmPOWER Territory Only)	Q3 2012 - Q2 2013 Tracking Data	Tracking Data % of Sales Data
15 SEER	3,635	4,779	131%
16+ SEER	4,812	2,152	45%
Total	8,447	6,931	82%

Source: Cadmus analysis

* ECM-adjusted distributor sales data / 36% (estimated percent of Maryland HVAC market covered by the distributor sales data) x 84% (estimated percent of Maryland residential customers who are a customer of an EmPOWER utility)

By comparison, the evaluation team surveyed participating and non-participating contractors in 2010, at which time participating contractors reported that about 45% of their high-efficiency CAC sales and 50% of their high-efficiency ASHP sales received program rebates. [36] Although this difference suggests that contractors are now applying for rebates for a larger portion of their high-efficiency sales than in 2010, conclusive results cannot be drawn because the 2010 and 2013 results come from two very different data sources.

[36] EmPOWER Maryland 2011 Evaluation Report Chapter 6: Residential Heating, Ventilation and Air Conditioning Program (HVAC), March 8, 2012. Section B.3.1, page 78.

G.2.2. Participant Phone Surveys

Participating Customer Freeridership Analysis

Freeriders are program participants who would have purchased the same efficient measure at the same time in the program's absence. The evaluation team developed a freeridership score for each surveyed participant based on the participant's surveys responses. Cadmus has developed a matrix approach that assigns a single score to each participant, based on objective responses.[37] Each participant's responses are translated into a matrix value to which a rules-based calculation is applied to obtain the final freeridership score. This matrix approach provides these important benefits:

- The ability to derive a partial freeridership score. These scores are based on the respondents' estimates of how likely they are to take similar actions in the absence of an incentive. Thus, the analysis can make use of "don't know" and "refused" responses rather than rejecting a data point.
- The use of a consistent, rules-based approach for each freeridership score.
- The ability to change weightings in a "what if" exercise to test sensitivity of responses to a variety of weighting scenarios.

Appendix I (page 89) contains information on how each survey response option was converted into a value of "yes," "no," or "partial," which refers to whether a respondent's answer was indicative of freeridership.

Appendix J (page 90) contains the freeridership score combinations used to categorize customer survey responses. The team's process for scoring is described in these bullet points:

- If customers did not know about a measure before hearing about the program and had no plans to install the measure, they are categorized as 0% freeriders.
- If customers did know about the program, but had no plans to install a measure, they are categorized as 0% freeriders.
- If customers either would have installed the measure without the program or had previously installed the measure before learning about the program, they are categorized as 100% freeriders.
- A partial freeridership score is assigned to customers who had plans to install the measure, but for whom the program exerted some influence over their decision. (The influence may have involved installation timing, the number of measures installed, or the efficiency levels of measures installed. For instance, where the program had less

[37] Khawaja, S. The NAPEE Handbook on DSM Evaluation, 2007 edition, page 5-1.

influence over the decision and the customer was highly likely to install a measure, a higher freeridership percentage is awarded.)

The evaluation team translates survey responses into matrix values to determine each participant's freeridership score. The team used the individual scores from the 173 participant phone surveys and the program measures evaluated savings to calculate a weighted-by-evaluated-savings average statewide freeridership score for each program measure category. The team did not develop utility specific program measure category freeridership estimates due to low sample sizes.

Using the equation below, freeridership calculations are weighted by the evaluated savings associated with each installed measure. This method ensures that respondents who achieved higher energy savings through program measures are given a greater influence on the final freeridership estimate than those respondents who achieved lower energy savings.

$$Weighted\ by\ Savings\ Freeridership\ \% = \frac{\sum \text{Each Respondent's FR Score x FR Measure kWh Savings}}{\sum \text{Program Measure kWh Savings for All Survey Respondents}}$$

Participating Customer Spillover Analysis

Participant spillover comes from customers' decisions to invest in additional efficiency measures beyond those rebated through the program. The evaluation team measured spillover by asking participating customers if, as a result of their participation in the program, they either decided to install any other efficiency measure or undertook any other efficiency-improving activities. The team asked participants to report the program's relative influence on their decisions to pursue these additional savings. (See questions D1-3 in the customer survey instrument, found in Appendix H, page 87.)

Cadmus applies evaluated gross savings to the spillover measures that customers said they installed after participating in the program. The spillover percentage for a measure is calculated as follows: dividing the sum of additional spillover savings reported by participants across the whole program for a given measure by the total reported gross savings achieved by program respondents for that measure (as reported in the customer survey). The equation for this relationship is:

$$Spillover\ \% = \frac{\sum \text{Spillover Measure Evaluated Gross kWh Savings for All Survey Respondents}}{\sum \text{Program Measure Evaluated Gross kWh Savings for All Survey Respondents}}$$

This information is then combined with the program-level freeridership results to achieve the NTG ratio, using the calculation:

NTG = 1 – Freeridership + Spillover

G.3. *Findings*

G.3.1. Standard Market Practice Study

The evaluation team considers the "System Allocations" in Table 57 and Table 58 to most accurately reflect the CACs and ASHPs installed in Maryland. However, the ECM adjustment uses qualitative feedback from a small, select group of contractors whose responses may not definitively represent standard practices in the state.

Also, the data collected from distributors represents 36% of the total statewide CAC and ASHP sales. Although this is a significant increase from the amount of data collected in 2012, it remains a fairly insignificant, and possibly unrepresentative, portion of the total annual sales. Additionally, the data presents potential bias since all distributors who participated in the study are partnering with at least one of the EmPOWER Residential HVAC programs.

Therefore, the evaluation team does not feel that results from this study are conclusive enough to apply to the Residential HVAC program NTG analysis.

G.3.2. Participant Phone Survey

To provide statistically significant freeridership results at the utility and measure level, the evaluation team used a combination of 2013 and 2012 participant survey data to estimate freeridership for each utility. The reported freeridership for the program overall is based on responses from 173 participants. The team surveyed 101 survey respondents in 2013 and 72 survey respondents in 2012.

Table 61 shows the freerider summary by utility after applying statewide freeridership estimates to each utility's ex-post gross evaluated population savings.

Table 61. Freeridership Summary*

Utility	N	Freeridership	Absolute Precision
BGE	43	64%	± 5%
PHI	44	63%	± 5%
PE	43	67%	± 8%
SMECO	43	66%	± 5%

All Utilities	**173**	**64%**	**± 5%**

*Uses 2012 and 2013 participant survey data

Table 62 shows freeridership rates from past EmPOWER Residential HVAC program evaluation reports and from other utilities' residential HVAC programs that use comparable self-report freeridership methodologies. With the exception of Midwest Utility – 2012, all EmPOWER utilities' freeridership estimates are generally higher than the other listed states' estimates.

Table 62. Comparable HVAC Program Freeridership Estimates

HVAC Study	Program Year	Freeridership
EmPOWER - Overall	2012	62%
EmPOWER - Overall	2011	57%
Midwest Utility	2012	63%
Midwest Utility	2011	54%
Midwest Utility	2011	49%
Southwest Utility	2011	52%

Table 63 shows the results of freeridership calculations for the EmPOWER Residential HVAC program measures.

Table 63. Freeridership Summary by Measure Type*

Measure	N	Freeridership	Absolute Precision
Air-Source Heat Pump	98	65%	± 6%
CAC	61	57%	± 8%
Other	14	69%	± 17%
Overall	**173**	**64%**	**± 5%**

*Uses 2012 and 2013 participant survey data

** Surveyed measures encompassed in the 'Other' category include Gas Furnace Tier 1 – ECM, GSHP, HVAC Tune-up, and Ductless Heat Pump.

Table 64 shows the unique survey response combinations from the EmPOWER Residential HVAC participant survey for:

- ASHP, CAC, tune-up, geothermal HP, and gas furnace measures
- The freeridership score assigned to each combination; and
- The number of responses for each combination.

Table 64. Frequency of Freeridership Scoring Combinations*

FR1 When you first heard about the rebate from [UTILITY], had you already been planning to purchase the [MEASURE]?	FR2. Had you ALREADY ordered or installed the [MEASURE] BEFORE you heard about the [UTILITY] rebates?	FR3. [IF FR2 = 2, -98, -99] Would you have installed the same [MEASURE TYPE] without the incentive from [UTILITY]?	FR4. [IF FR3 = 2, -98, OR -99] Would you have installed a different [MEASURE] without the [UTILITY] program incentive or would you have installed nothing?	FR5. [IF FR3 = 1 OR FR4 = 1] When you say you would have installed a [MEASURE TYPE], would you have installed the same one that was just as energy efficient?	FR6. [IF FR3 = 1 OR FR4 = 1] Without the [UTILITY] rebate, would you have installed the same equipment [READ LIST]:	FR7. [IF FR4 = 2] When you say you would not have installed the same [MEASURE TYPE], do you mean you would not have installed a [MEASURE TYPE] at all?	FR8. [IF FR7 = 2, -98, -99] Would you have installed the same type of [MEASURE TYPE] but [it/they] would not have been as energy-efficient?	FR9. [ASK IF FR7=2, -98, -99] And, would you have installed the same [MEASURE TYPE]	Free-Ridership Score	Frequency
Yes	Yes	x	x	x	x	x	x	x	100%	38
Yes	No	Yes	x	Yes	Yes	x	x	x	100%	70
Yes	No	Yes	x	Yes	Partial	x	x	x	75%	2
Yes	No	Yes	x	Yes	No	x	x	x	0%	9
Yes	No	Yes	x	Partial	Yes	x	x	x	75%	2
Yes	No	Yes	x	No	x	x	x	x	0%	1
Yes	No	Partial	Yes	Yes	No	x	x	x	0%	1
Yes	No	Partial	Yes	Partial	Yes	x	x	x	50%	1
Yes	No	Partial	Yes	Partial	No	x	x	x	0%	1
Yes	No	Partial	Partial	x	x	x	x	x	0%	1
Yes	No	No	Yes	Yes	Yes	x	x	x	50%	6
Yes	No	No	Yes	Partial	Yes	x	x	x	25%	2

Yes	No	No	Yes	No	x	x	x	x	0%	7
Yes	No	No	Partial	x	x	x	x	x	0%	1
Yes	No	No	No	x	x	No	x	x	0%	2
Partial	Yes	x	x	x	x	x	x	x	100%	1
Partial	No	Yes	x	Yes	Yes	x	x	x	75%	1
Partial	No	No	Yes	Partial	No	x	x	x	0%	1
No	No	Yes	x	Yes	Yes	x	x	x	50%	10
No	No	Yes	x	Yes	No	x	x	x	0%	2
No	No	Yes	x	Partial	Yes	x	x	x	25%	2
No	No	Partial	Yes	Yes	Yes	x	x	x	25%	1
No	No	Partial	Partial	x	x	x	x	x	0%	2
No	No	Partial	No	x	x	No	x	x	0%	1
No	No	Partial	No	x	x	Yes	Yes	Yes	25%	1
No	No	No	Yes	Yes	No	x	x	x	0%	2
No	No	No	Yes	No	x	x	x	x	0%	4
No	No	No	No	x	x	No	x	x	0%	1

*Uses 2012 and 2013 participant survey data

Table 64 presents response patterns from all 173 survey participants. Four patterns commonly occurred in 140 respondents' answers to the freeridership battery, representing 81% of the 173 participants included in the freeridership analysis. These four common patterns are summarized as follows:

- 70 survey respondents said they had specific plans to purchase the same measure that the program offered at the same level of efficiency before learning about the EmPOWER rebate, and that they would have done so within the same year. (Respondents in this category were scored as 100% freeriders.)
- 38 respondents said they already had ordered or purchased the same measures before hearing about the EmPOWER rebate. (These were scored as 100% freeriders.)
- 16 respondents said they would not have installed the HVAC equipment within the same year without the EmPOWER rebate. (These were scored as 0% freeriders.)
- 16 respondents answered they would not have installed the HVAC equipment to the same level of efficiency had they not received the EmPOWER rebate. (These were scored as 0% freeriders.)

The remaining 33 respondents (19% of all 173 survey participants) answered in unique patterns that received scores rated between 0% and 100% freeridership. These 33 scores are also included in Table 64.

Scoring Adjustments

The evaluation team used a multiple-question approach to assess the freeridership score for each participant. This methodology provides a standardized and rigorous approach to measuring a complex concept: what would have the participant done in absence of the program? In the majority of cases, this is a challenging question for participants to answer directly and accurately, which is why addressing it through several indicators facilitates the best approach for determining each participant's score, as opposed to relying on just one question.

Even with the multi-question approach to scoring freeridership, bias may still be present.

- **Social desirability bias** occurs when the respondent tells you what he or she believes to be the "best" answer, which in this case would be purchasing the most energy-efficient product without the rebate.
- **Recall bias** occurs when the respondent has difficulty remembering what they did in the past, or, what they would have done in a hypothetical situation based on past needs, desires, or motivations.

To control for these common self-report biases in our freeridership results, the evaluation team included an additional question in the freeridership battery that was not used in the initial scoring process. This question was:

"Please tell me how important the (UTILITY) rebate offer was on your decision to purchase this high efficiency equipment?"

a. *Important*
b. *Somewhat important*
c. *Not very important*
d. *Not at all important*

If responses to the question are contradictory to the answers reported in the initial freerider scoring questions, the evaluation team made adjustments to control for possible social desirability response bias known to impact self-reported freeridership findings. The adjustments for the survey respondents were as follows:

- Respondents with an initial 100% freeridership score who answered that the EmPOWER energy efficiency promotion was "Important" to their purchasing decision received a final freeridership score of 50%.
- Respondents with an initial 100% freeridership score who answered that the EmPOWER energy efficiency promotion was "Somewhat important" received a final freeridership score of 75%.
- Respondents with an initial 0% freerider score who also answered that the EmPOWER energy efficiency promotion was "Not at all important" to their purchasing decision received a final freeridership score of 50%.
- Respondents with an initial 0% freerider score who also answered that the EmPOWER energy efficiency promotion was "Not very important" to their purchasing decision received a final freeridership score of 25%.

The evaluation team reviewed all responses and adjusted 56 (32%) freeridership scores according to the above method. Table 65 indicates the magnitude and the direction of the adjustments that were made to participants' freeridership estimates.

Table 65. Adjusted Freeridership Scores

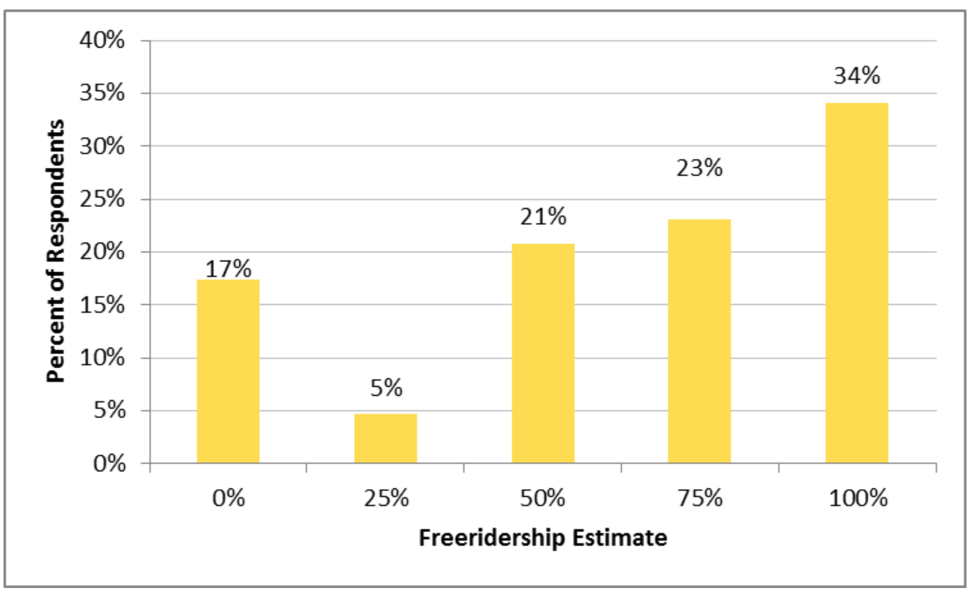
Number of Responses	Original Freeridership	Adjusted Freeridership
35	100%	75%
15	100%	50%
4	0%	50%
2	0%	25%

Freeridership Distribution by Score

Figure 7 shows the distribution of all 173 respondents by each one's final freeridership score.

- Approximately 17% of survey respondents were scored as 0% freeriders;
- 5% of respondents exhibited low levels of freeridership (25%);
- 44% of respondents exhibited moderate level of freeridership (50% and 75%); and
- 34% were scored as true freeriders (100%).

Figure 7. Freeridership Distribution by Score*



* Uses 2012 and 2013 participant survey data and final freeridership scores

Participating Customer Spillover Results

The spillover estimate is based off data obtained from only the 2013 participant survey. Table 66 shows six 2013 survey respondents out of the 101 surveyed (6%) indicated their participation in the Residential HVAC program was "very influential" (using a scale of 1 to 4) on their decisions to take additional energy-efficient actions.

Table 66. Spillover by Measure*

Utility	Spillover Measure	kWh Savings
BGE	Water Heater	508
BGE	Refrigerator	139
BGE	Windows	99
BGE	50 CFLs	1,220
SMECO	R-60 Insulation	271
SMECO	Thermostat	129
Total		**2,366**

*Uses 2013 participant data only

As shown in Table 67, the evaluation team estimates spillover at 12% of BGE's survey sample program kWh savings and 2% of SMECO's survey sample program kWh savings. The table also shows program-level spillover, estimated to be 3% of total energy savings attributable to the program when combining estimated spillover measures across all utilities. For reporting purposes, the 3% program-level estimate was applied to each utility's NTG calculations.

$$Spillover\ \% = \frac{\sum \text{Program Evaluated Gross Spillover kWh Savings for All Survey Respondents}}{\sum \text{Total Evaluated Gross Program kWh Savings for All Survey Respondents}}$$

Table 67. Spillover Estimate*

Utility	Evaluated Spillover kWh Savings	Evaluated Program kWh Savings	Spillover
BGE	1,966	16,780	12%
PHI	0	20,621	0%
PE	0	16,803	0%
SMECO	400	25,868	2%

Overall	**2,366**	**80,072**	**3%**

*Uses 2013 participant data only

Note: Values reported in the table are rounded.

Participating Customer NTG Calculation

The evaluation team calculated the NTG rate using the following algorithm:

$$NTG = 1 - Freeridership + Spillover$$

Combining freeridership and spillover calculations yielded an overall NTG estimate of 39% for the EmPOWER Residential HVAC program. Table 68 shows NTG estimates by utility.

Table 68. Freeridership, Spillover and NTG, by Utility

Utility	Freeridership	Spillover	Net-to-Gross
BGE	64%	3%	39%
PHI	63%	3%	40%
PE	67%	3%	36%
SMECO	66%	3%	37%
Overall	**64%**	**3%**	**39%**

Utility level NTG estimates are somewhat lower than other evaluations listed in NTG ratios are generally low for all of these programs. The EmPOWER 2013 Residential HVAC process evaluation memo explores utilities' marketing tactics that likely affect the freeridership levels and provides recommendations that could help improve these NTG ratios.
Table 69 that use a comparable self-report NTG methodology; however, NTG ratios are generally low for all of these programs. The EmPOWER 2013 Residential HVAC process evaluation memo explores utilities' marketing tactics that likely affect the freeridership levels and provides recommendations that could help improve these NTG ratios.

Table 69. Comparable HVAC Program's NTG Estimates

Utility	Program Year	Freeridership	Spillover	NTG Ratio
EmPOWER - Overall	2012	62%	2%	40%

EmPOWER - Overall	2011	57%	0%	43%
Midwest Utility	2012	63%	2%	39%
Midwest Utility	2011	54%	0%	46%
Midwest Utility	2011	49%	1%	52%
Southeast Utility	2011	52%	2%	50%

G.4. Statistical Significance

The evaluation team estimated the precision for the NTG ratios for the HVAC program using industry best practices, as outlined in the USDOE's Uniform Methods Project. [1] First the team estimated the standard errors of the total net savings for each stratum:

$$SE(Total\ Net\ kWh_h) = \left(\frac{Population\ Mean\ Gross\ kWh_h}{Sample\ Mean\ Gross\ kWh_h}\right)\sqrt{\left(\frac{N_h^2}{n_h}\right)\left(1-\frac{n_h}{N_h}\right)\frac{\sum(Net\ kWh_i - NTGR_h * Gross\ kWh_i)^2}{n_h - 1}}$$

This formula is the standard calculation for strata level estimates from a ratio estimator, such as the NTG ratio. The evaluation team then calculated the final program-level total net savings standard errors using the following formula:[2]

$$SE(Program\ Total\ Net\ kWh) = \sqrt{\sum SE(Total\ Net\ kWh_h)^2}$$

Finally, the team calculated absolute precision values for NTG ratios using the following formula.

$$Absolute\ Precision = t_{1-\alpha} * \frac{SE(Program\ Total\ Net\ kWh)}{Total\ Gross\ kWh}$$

Where:

t = the t-statistics for the confidence level, 1-α; and

[1] See the USDOE's Uniform Methods Project, Chapter 11: Sample Design Cross-Cutting Protocols (http://www1.eere.energy.gov/wip/pdfs/53827-11.pdf) for details on these and related formulas.

[2] This formula calculates standard error for total savings conditional on gross savings. That is, the formula assumes that gross savings is a known value. While this is appropriate for the estimation of the NTG ratio, a complete estimation of the uncertainty of total net savings would need to incorporate the uncertainty from both the NTG ratio and the gross savings calculations.

1-α = the one-tailed confidence level.

Table 70 shows the final precision estimates for the NTG ratios, by utility.

Table 70. NTG Ratio Precision by Utility

Utility	Net-to-Gross	Absolute Precision
BGE	0.39	± 3%
PHI	0.40	± 3%
PE	0.36	± 12%
SMECO	0.37	± 2%
Overall	**0.39**	± 4%

Appendix H: Deemed Savings Recommendations for TRM

Table 71 provides a summary of recommended update to the Mid-Atlantic TRM Version 3.0. All values for updates are provided in this evaluation report with the sources and table numbers cited in the last column of Table 71.

Table 71. Recommended TRM Updates

TRM Measure Group	Parameter*	TRM v3.0	Recommendation	Source
Residential HVAC	ECM kW Savings	162.5 W x coincidence factor	0 kW	Evaluation team field testing
	ENERGY STAR Central A/C kWh	Uses EFLH from BGE study in 2007	EY4 EFLH Values	Evaluation Table 30
	ENERGY STAR Central A/C kW	Uses coincidence factor from 2007 BGE study	EY4 EFLH Values	Evaluation Table 20
	Air-Source Heat Pump kWh	Uses EFLH from BGE study in 2007	EY4 EFLH Values	Evaluation Table 30
	Air-Source Heat Pump kW	Uses coincidence factor from 2007 BGE study	EY4 EFLH Values	Evaluation Table 20

Appendix I: Participant Phone Verification Survey

EmPOWER_EY4
HVAC Participant Surv

Appendix J: Customer Participant Freeridership Survey Response Options Converted to Scoring Matrix Terminology

Appendix D_Freeridership Scori

Appendix K: Customer Participant Freeridership Scoring Matrix

Appendix
E_Freeridership Scori