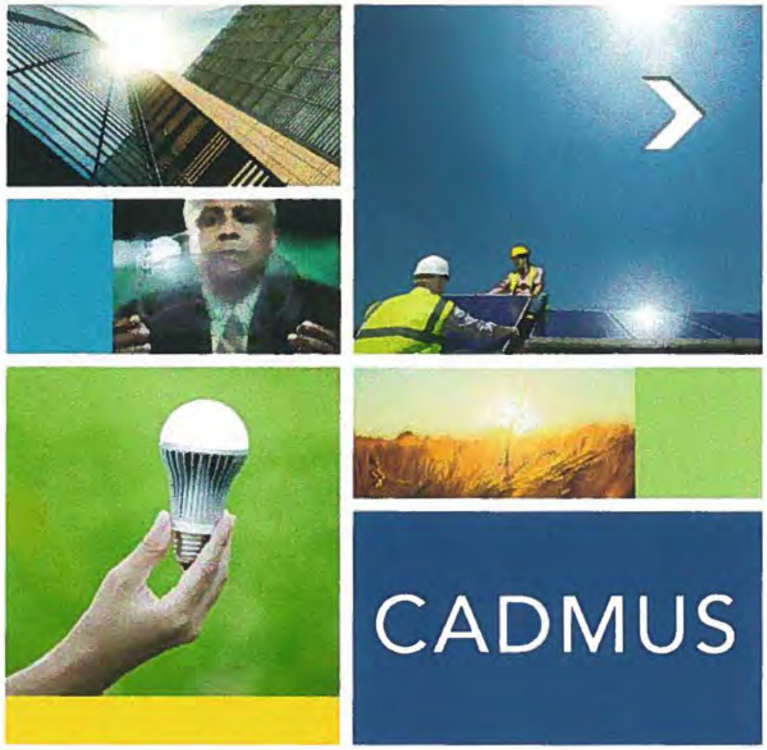

Evaluation of the Residential Smart $aver HVAC Program in Ohio and Kentucky

September 21, 2015

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Introduction

The Duke Energy Ohio and Kentucky Residential Smart $aver HVAC program encourages the installation of higher efficiency heating and cooling units in new and existing homes. Cadmus evaluated the program from January 2012 through October 2013. To estimate energy consumption for each HVAC system installed through the program, we used post-installation monthly electric bills and participation tracking information. To estimate each system's energy savings, we relied on local weather data and performed engineering calculations.

The evaluation findings presented in this report represent the savings for installation of high-efficiency central heat pump and air conditioners.

Program Description

Through Duke Energy's Residential Smart $aver HVAC program, residential customers, vendors, and home builders can receive a rebate for installing higher efficiency heating and cooling units in new and existing homes. The HVAC system must include an electronically commutated motor (ECM) fan. Residential customers receive rebates of $200 on qualified purchases. An additional $100 incentive goes directly to the participating HVAC contractor or dealer. New home builders who install qualified equipment are eligible for rebates of $300.

Duke Energy in Ohio and Kentucky contracts with a third-party vendor, GoodCents, which is responsible for daily administration of the program, including HVAC dealer and contractor recruitment, call center operations, rebate application processing and payments, and quality assurance. Participating trade allies discuss the program with Duke Energy Ohio and Kentucky customers who are considering the purchase of a replacement air conditioner or heat pump. At the point of sale, the trade ally presents the $200 incentive to the customer for selecting the high efficiency equipment option. After installing the qualifying unit, the trade ally fills out a rebate application form and submits it with a copy of the invoice and a certificate from the American Heating and Refrigeration Institute (AHRI). Within 45 days, GoodCents processes the paperwork and mails the checks ($100 to the contractor and $200 to the customer). New home builders can opt to keep the $300 rebate or pass it along to the home buyer.

Cadmus evaluated program participation during January 2012 through October 2013. Duke Energy database contains 7,505 participant records during this period[1].

[1] To estimate savings for any additional or missing measure participation (not included in the database used by Cadmus), use average savings values in Table 9 (784 kWh for air conditioners, 1,113 for heat pumps).

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Evaluation Objectives

In collaboration with Duke Energy in Ohio and Kentucky, Cadmus identified these impact evaluation objectives:

- **Estimate gross energy savings for central air conditioning systems.** Estimate savings for unitary installation of a central air conditioning system using all available data and engineering calculations.
- **Estimate gross energy savings for central heat pump systems.** Estimate savings for unitary installation of a central heat pump system using all available data and engineering calculations.
- **Estimate net savings.** Determine freeridership and spillover savings attributable to the Smart $aver program.

High-Level Impact Findings

This section summarizes the Cadmus Team's key impact findings.

Gross Impacts

As shown in Table 1 and Table 2 the Residential Smart $aver HVAC Program exceeded its gross energy and demand savings goals.

Table 1. Program Projected, Claimed, and Evaluated Gross Energy Impacts

Program	# Units Incented	Reported* Savings (kWh)	Evaluated** Savings (kWh)
Smart $aver Central Air Conditioner	5,201	2,039,296	4,076,392
Smart $aver Central Heat Pump	2,304	3,550,541	2,564,822
Total	**7,505**	**5,589,837**	**6,641,214**

* Based on tracking database provided to Cadmus.
**Based on average savings by system type and mode of operation. Per-unit average gross savings of 784 kWh/central air conditioner and 1,113 kWh/heat pump.

Table 2. Program Projected, Claimed, and Evaluated Gross Peak Demand Impacts

Program	# Units Incented	Reported* Savings (kW)	Evaluated** Savings (kW)
Smart $aver Central Air Conditioner	5,201	1,023	2,406
Smart $aver Central Heat Pump	2,304	453	889
Total	**7,505**	**1,476**	**3,295**

* Based on tracking database provided to Cadmus.
** Calculated using DSMore with monthly energy savings values (see Table 8).

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Net Impacts

Based on the 7,505 central air conditioner and heat pump units incented through the Smart $aver HVAC program, the overall net energy and demand savings from the program was 4,144,118 kWh and 2,056 summer coincident peak kW (Table 3 and Table 4).

Table 3. Program Net Energy Impacts

Program	# Units Incented	Average Savings per Unit (kWh)	Evaluated Savings (kWh)
Smart $aver Central Air Conditioner	5,201	489	2,543,669
Smart $aver Central Heat Pump	2,304	695	1,600,449
Total	**7,505**	**552**	**4,144,118**

Table 4. Program Net Peak Demand Impacts

Program	# Units Incented	Average Savings per Unit (kW)	Evaluated Savings (kW)
Smart $aver Central Air Conditioner	5,201	0.289	1,502
Smart $aver Central Heat Pump	2,304	0.241	555
Total	**7,505**	**0.274**	**2,056**

Evaluation Parameters

The Cadmus team used multiple activities and analyses to conduct the impact evaluation of the Residential Smart $aver HVAC Program. Table 5 lists the parameters of these activities, along with the estimated precision values at the 90% confidence level. Heating and cooling precision estimates are based on the variance in consumption from billing analysis results, normalized by system size (tons). A census[2] of participants was used to determine heating and cooling consumption kWh/ton values.

Table 5. Evaluated Parameters with Value, Units, and Precision and Confidence

Parameter	Sample Size	Units	Confidence/Precision
Cooling Consumption Estimate from Billing Analysis	6,807 utility bills	kWh/ton grouped by installation type	90% confidence with ±2% precision
Heating Consumption Estimate from Billing Analysis	2,389 utility bills	kWh/ton grouped by installation type	90% confidence with ±4% precision
Freeridership score	67 Vendor allies	% Freeridership	90% confidence with ±14.4% precision

[2] A total of 7% of participant service accounts were removed (see section: Method – Billing Analysis) for various reasons thus these were not included in the precision estimate.

Table 6 lists the start and end dates for activities conducted for the impact evaluation.

Table 6. Sample Period Start and End Dates

Evaluation Component	Sample Period	Dates Conducted	Total Conducted
HVAC Vendor Freeridership Surveys	Participation in 2012 and 2013	September 2013	67
Billing Analysis	Varies* (2012-2014)	May 2015	6,807

*Post-installation billing data used. In some cases two years of data were available so two separate results were calculated for one participant service account. In these cases we chose the consumption estimate with the higher R-square value.

Method

Cadmus relied on primary and secondary data to evaluate the Smart $aver HVAC program. We used PRISM software to estimate the heating and cooling HVAC load for each participant from monthly utility bills. To estimate consumption by unit rather than by participant, we grouped billing analysis results of each participant by type of installation as specified in the tracking database.[3] We used HVAC energy consumption estimates from billing analysis with local weather station data to predict energy consumption in normal temperature (typical meteorological year 3 [TMY3]) bins. We relied on secondary research to estimate ECM savings. We then applied manufacturer's equipment specifications to calculate savings for each type of HVAC system installed. We describe each of these methods in the next sections.

Method – Billing Analysis

Cadmus conducted a statistical billing analysis on a minimum of 10 months of post-installation period billing data, using PRISM software to determine the most recent use. We followed these steps:

1. Matched the measure-tracking information with the electric billing data. Billing data was received from January 2012 through October 2014.
2. Used ZIP code mapping for all weather stations in the United States to determine the nearest station for each ZIP code of the participants' billing addresses.
3. Obtained daily average temperature weather data from January 2011 through 2014 for ten National Oceanic and Atmospheric Administration (NOAA) weather stations, representing all ZIP codes of the participants' billing addresses.
4. Used daily temperatures to determine base 45–85 heating degree days (HDDs) and cooling degree days (CDDs) for each station.

[3] Cadmus grouped all participants who installed only one central air conditioning or heat pump unit separately from all participants who installed more than one unit.

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5. Matched billing data periods with the CDDs and HDDs from the associated stations.

We removed 7% of the sites from our analysis because of these criteria:

- Any service account with a ground source heat pump
- Any service account with less than 300 days of data
- Some results with very low R-square
- Any results when the model overpredicted total consumption by more than 150% of actual and less than 50% of actual

For each participant service account, we estimated a heating and cooling PRISM model in the post-installation periods to weather-normalize raw billing data. Each model allowed the heating reference temperature to range from 45°F to 85°F and the cooling reference temperature to range from the heating reference temperature to 85°F.

The PRISM model used the following specification:

$$ADC_{it} = \alpha_i + \beta_1 AVGHDD_{it} + \beta_2 AVGCDD_{it} + \varepsilon_{it}$$

Where for each customer 'i' and calendar month 't':

ADC_{it}	=	the average daily kWh consumption in the post program period.
α_i	=	the participant intercept; represents the average daily kWh base load.
β_1	=	the model space heating slope.
β_2	=	the model cooling slope.
$AVGHDD_{it}$	=	the base 45°F to 85°F average daily HDDs for the specific location.
$AVGCDD_{it}$	=	the base 45°F to 85°F average daily CDDs for the specific location.
ε_{it}	=	the error term.

Using this PRISM model, we computed weather-normalized annual consumption (NAC) for each heating and cooling reference temperature, as follows:

$$NAC_i = \alpha_i * 365 + \beta_1 LRHDD_i + \beta_2 LRCDD_i + \varepsilon_i$$

Where for each customer 'i':

NAC_i	=	the normalized annual kWh consumption.
α_i	=	the intercept is the average daily or base load for each participant; it represents the average daily base load from the model.
$\alpha_i * 365$	=	the annual base load kWh usage (non-weather sensitive).
β_1	=	the heating slope; in effect, this is usage per heating degree day from the model above.
$LRHDD_i$	=	annual, long-term HDDs of a typical month year normal (TMY3) in the 1991–2005 series from NOAA, based on the home location.
$\beta_1 \cdot LRHDD_i$	=	the weather-normalized annual weather sensitive heating usage, also known as HEATNAC.

β_2	=	the cooling slope; in effect, this is usage per CDD from the model above.
$LRCDD_i$	=	annual, long-term CDDs of a typical month year (TMY3) in the 1991–2005 series from NOAA, based on home location.
$\beta_2 * LRCDD_i$	=	the weather-normalized annual weather sensitive cooling usage, also known as COOLNAC.
ε_i	=	the error term.

If any heating and cooling model yielded negative intercepts, negative heating slopes, or negative cooling slopes, we estimated additional models that separated out only the cooling usage (cooling-only models) or the heating usage (heating-only models). From the models with correct signs on all parameters, the best model chosen for each participant for the post-installation periods was the one with the highest R-square. To obtain the HVAC use, we added up the heating and cooling NACs. We determined HVAC consumption separately for the following seven participant groups:

- Cooling: 1 cooling system; heating: 1 heat pump, no gas furnace
- Cooling: 1 cooling system; heating: 1 heat pump with gas furnace
- Cooling: 1 cooling system; heating: no electric heating
- Cooling: 2+ cooling systems; heating: 1 heat pump, no gas furnace
- Cooling: 2+ cooling systems; heating: 1 heat pump with gas furnace
- Cooling: 2+ cooling systems; heating: multiple electric heating systems
- Cooling: 2+ cooling systems; heating: no electric heating

We separated results in this way for several reasons, including:

- Heat pumps installed with gas furnaces are unlikely to have backup electric resistance heat, so all electric heating consumption is from the evaporator/condenser.
- To investigate consumption differences of homes with one system versus homes with multiple systems.
- To compare cooling consumption and savings of heat pumps to air conditioners.

Note that these observations cannot be confirmed because they are based only on reported data in the tracking database. For example, a home could have multiple air conditioners but only one may have been installed using a rebate. In this scenario, our analysis would overestimate consumption and savings for that type of HVAC system reported in the tracking database.

Method – ECM Savings Estimates

We used data collected from previous Cadmus metering studies to estimate savings from ECM fan in heating mode for air conditioners and in circulation mode for both air conditioners and heat pumps. ECMs typically save energy in three ways:

- Cooling mode savings

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- Heating mode savings
- Circulation mode savings

Seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF) ratings include the benefit of the ECM fan. ECM fan savings in cooling mode, therefore, are accounted for. Savings attributable to an ECM fan in heating mode are accounted for by the HSPF rating of a heat pump. An ECM fan does save energy for an air conditioner installed with a heating system, so we estimated heating mode savings for all air conditioners using a large-scale metering study performed by Cadmus in Wisconsin.[4] We adjusted the heating mode savings for run time by a ratio of HDD.

To determine savings in circulation mode, we used the same Wisconsin metering study and another large (160 HVAC units) fan metering study conducted by Cadmus for a Midwest utility in 2013.[5] We found that the average circulation mode run time of a typical HVAC system is approximately 8%. This results in a circulation mode savings for both air conditioners and heat pumps of 153 kWh.

Method – Heating and Cooling Savings Calculations

Cadmus developed savings models that use normal bin temperature data (typical meteorological year 3 [TMY3]) to estimate cooling savings for both air conditioners and heat pumps and to estimate the heating savings for heat pumps. The federal minimum efficiency of a heat pump and air conditioner through 2014 was 13 SEER (and 7.7 HSPF for heat pumps in heating mode). All savings are based on the assumption that an HVAC system of this efficiency with a standard permanent split capacitor (PSC) fan would have been installed even if the Smart $aver incentive was not available.

Our spreadsheet models estimated savings with the same general principle as DOE-2-based residential energy models.[6] The calculated savings are based on HVAC consumption estimated from billing analysis; with a spreadsheet model, we are able to quickly make adjustments and check the reasonableness of results. For example, we used the HDD and CDD base temperatures determined in the billing analysis to limit the HVAC consumption to a range of temperatures. If the HDD base temperature for a group was 58°F and the CDD base temperature was 65°F, we assumed cooling consumption occurs only above 65°F and heating consumption occurs only below 58°F.[7] To calibrate a model (such as BeOpt) to billing analysis results, the user must make changes to the building shell (change window size, increase/ decrease insulation values) that are unrealistic.

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[4] Wisconsin Focus on Energy. *Technical Reference Manual.* Prepared by Cadmus. August 15, 2014. Available online: https://focusonenergy.com/sites/default/files/Wisconsin%20Focus%20on%20Energy%20Technical%20Reference%20Manual%20August%202014.pdf

[5] Data from this study are not yet publicly available.

[6] U.S. Department of Energy. DOE-2 software is available online at http://www.doe2.com/.

[7] Group defined above as type of installation (e.g. air conditioner only, multiple HP systems).

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To determine savings by the SEER reported, we used the average HVAC consumption estimated by the groups defined in the Method – Billing Analysis section above and applied the simulated EER versus temperature curves developed from manufacturer's data. Figure 1 shows typical manufacturer data.

Figure 1. Example of HVAC Parameters used for Analysis

Single Stage

Rated Inputs
15.0 SEER
13 Rated EER
3.81 COP COP = EER / 3.413
36,000 BTUH_3_t Total Capacity

SINGLE STAGE

ODB	BTUH	kW	EER	EIR
65	37,351	1.98	18.85	0.181
75	35,986	2.17	16.58	0.206
85	34,529	2.43	14.20	0.240
95	32,980	2.75	11.99	0.285
105	31,340	3.11	10.08	0.339
115	29,609	3.49	8.49	0.402

	a	b	c
EER	0.000933	-0.37802	39.55868
Capacity	-0.4572	-72.5605	43999.58
kW	0.000242	-0.01298	1.796721

Dual Stage

Rated Inputs
17.0 SEER
14.4 Rated EER
4.22 COP COP = EER / 3.413

LOW STAGE

ODB	BTUH	kW	EER	EIR
65	27,576	1.18	23.31	0.146
75	26,473	1.29	20.47	0.167
85	25,297	1.50	16.82	0.203
95	24,050	1.80	13.39	0.255
105	22,731	2.15	10.58	0.323
115	21,339	2.54	8.41	0.406

	a	b	c
EER	0.001187831	-0.52122	52.43768
Capacity	-0.360288	-59.8779	32990.04
kW	0.000351894	-0.03581	2.014131

Rated Inputs
17.0 SEER
13.2 Rated EER
3.87 COP COP = EER / 3.413

HIGH STAGE

ODB	BTUH	kW	EER	EIR
65	36,676	1.98	18.54	0.184
75	35,333	2.23	15.82	0.216
85	33,923	2.53	13.43	0.254
95	32,447	2.85	11.40	0.299
105	30,905	3.18	9.71	0.352
115	29,297	3.53	8.31	0.411

	a	b	c
EER	0.001682	-0.50715	44.39718
Capacity	-0.33084	-88.0434	43796.87
kW	0.000109	0.011625	0.758049

Efficiency varies with both outdoor and indoor conditions. We assumed 40% relative humidity and 75°F to represent the indoor temperature setpoint during the cooling season. We assumed 37% relative humidity and 70°F to represent the indoor temperature setpoint during the heating season.

We used bin temperature data for each weather station to estimate the proportion of energy consumption (estimated through billing analysis) in 1°F temperature bins. We assumed cooling energy consumed was proportional to cooling degree days. This assumption has been validated by numerous residential metering studies and review of end-use metering conducted at a sample of 24 air conditioner and 23 heat pump participant HVAC systems, metered from August to December 2013.[8] Figure 2 shows metered data from a participant with a central air conditioner. For this participant and most others, kWh consumption is relatively linear.

[8] The relationship between cooling kWh and CDD is typically linear, but we have seen that linearity may not uphold at extreme temperatures or during very hot years when utility customers experience billing fatigue.

Figure 2. Example of Duke HVAC Metering Data (Central Air Conditioner)

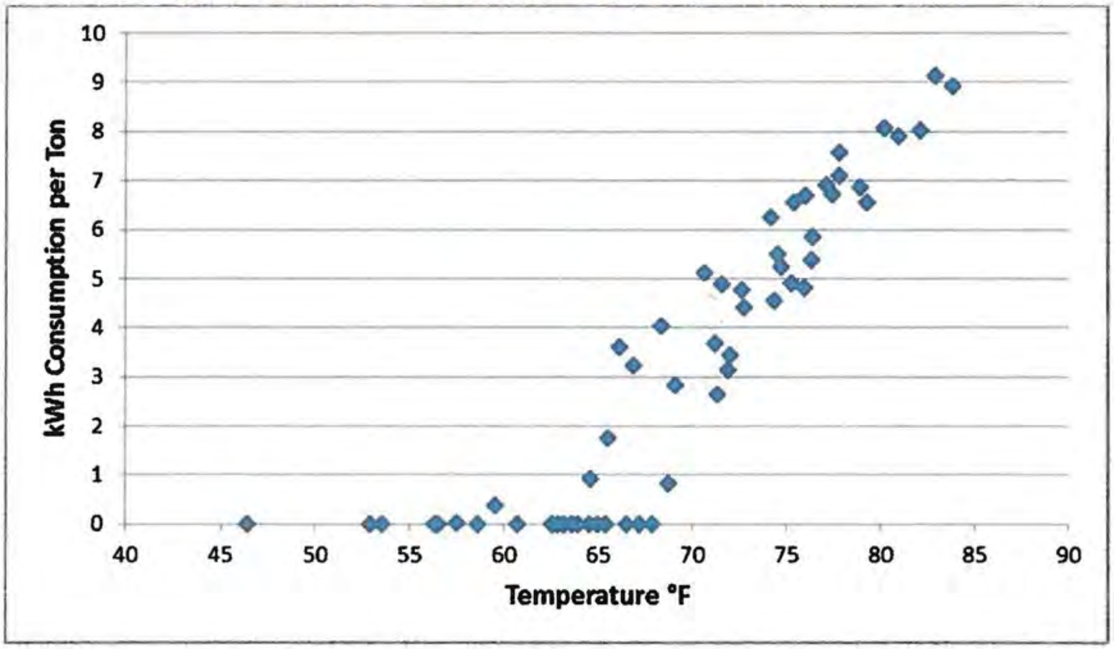
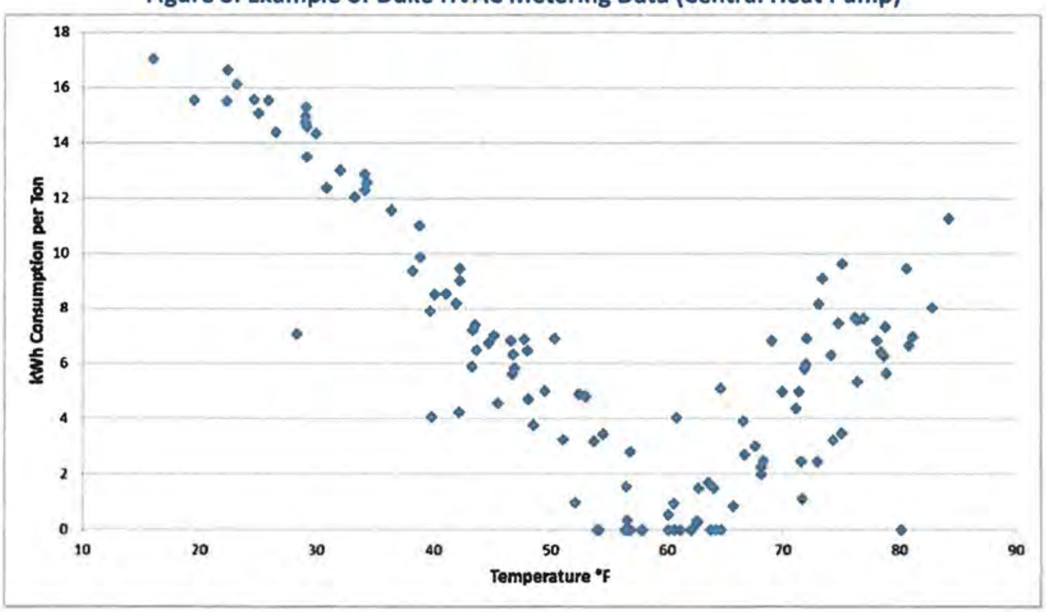


Figure 3 shows similar linearity in heating mode. We would expect some change in the curve to occur near the balance point (~20°F); however, only a small number of hours at or below this temperature were metered so the effect cannot be seen.

Figure 3. Example of Duke HVAC Metering Data (Central Heat Pump)



For multistage systems with higher proportional savings in the low stage, we estimated the temperature at which the system switched from low stage to high stage. We calculated a coincidence factor at each temperature bin using kWh consumed, estimated capacity (low stage), and estimated power. For temperatures when the coincidence factor was above 85%, we assumed that the system operated in high stage. The assumption that a unit operates in high stage when coincidence factor is above 85% is based on engineering judgment. Most of the systems we evaluated (approximately 94%) had only a single-stage operation, so even a large change to the assumption of 85% had minimal effect on calculated savings.

We estimated heat pump heating savings in 1°F temperature bins in the same way. We assumed a heat pump condenser sizing balance point of 20 degrees for all-electric heat pumps and 30 degrees for heat pumps with gas furnaces.[9] For heat pumps without gas furnaces, we assumed that energy consumption in each temperature bin below the balance point was a combination of backup electric resistance heat and heat pump energy consumption. We assumed a heat pump installed with a gas furnace does not operate below the balance point.

Results

This section summarizes results based on the evaluation objectives listed above (net savings methods and results are provided in a subsequent chapter). Table 7 shows the results of the monthly billing data HVAC disaggregation analysis.

Table 7. Duke Energy Ohio and Kentucky Billing Analysis Summary

Grouping	Service Accounts	Heat Pumps	Air Conditioners	Heating (kWh)	Cooling (kWh)
Cooling: 1 cooling system Heating: 1 HP no gas furnace	2,054	2,054	-	6,656	2,639
Cooling: 1 cooling system Heating: 1 HP with gas furnace	191	191	-	3,162	2,902
Cooling: 1 cooling system Heating: No electric heating	4,388	-	4,388	-	2,861
Cooling: 2+ cooling systems Heating: 1 HP no gas furnace	7	7	7	3,475	3,606
Cooling: 2+ cooling systems Heating: 1 HP with gas furnace	4	4	5	7,550	3,167
Cooling: 2+ cooling systems Heating: Multiple electric heating systems	57	123	-	9,104	5,725
Cooling: 2+ cooling systems Heating: No electric heating	106	10	209	-	4,903
Grand Total	**6,807**	**2,389**	**4,609**	**6,467**	**2,852**

[9] These balance points worked for most groups. We made some changes by a few degrees if the calculated heat pump consumption did not match billing analysis results.

To provide context, we offer the following observations to help interpret the billing analysis results for each row in Table 7:

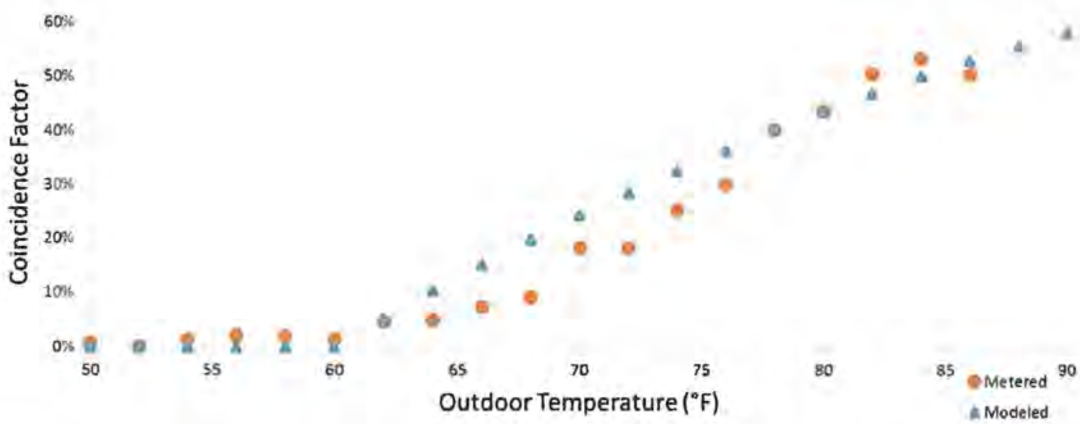
- ***Row 1.*** One system only, a heat pump. All heating and cooling energy consumption is used to estimate savings for one heat pump system.
- ***Row 2.*** One system only, a heat pump installed with a gas furnace. Heating energy consumption is much less than in row 1, as expected, because gas furnace provides some heat. This installation type has lower consumption but higher proportional savings because we assume the heat pump does not use any backup electric resistance (ER) heat, which has no savings potential.
- ***Row 3.*** One system only, an air conditioner. Billing analysis found some heating energy consumption but the estimates were unreliable, as expected. We set heating consumption to 0 kWh because we calculated heating savings from the ECM installation using secondary sources.
- ***Row 4.*** There was a low number of services accounts so the results have higher uncertainty. Seven services accounts had 14 total systems (seven air conditioners, seven heat pumps). The per-unit cooling consumption, therefore, is half of the consumption value estimated from the billing analysis.
- ***Row 5.*** See row 4.
- ***Row 6.*** This group includes participants with at least two and up to four heat pumps installed, none with gas furnaces. The heating and cooling consumption values per system, therefore, are lower than the values estimated by billing analysis.
- ***Row 7.*** Similar to row 6; however, the billing analysis found no heating energy consumption for the four heat pump systems (installed at two service accounts). Some possible explanations of this unexpected finding are:
    - Large number of heat pumps installed indicates a large home that may have low occupancy during the heating season.
    - Heat pumps could be installed with gas furnaces.
    - Issue or error in tracking database (systems installed actually air conditioners).

We used aggregate (average) HVAC energy consumption for each group defined in Table 7, rather than individual participant estimated HVAC consumption, to limit the uncertainty of the savings calculation estimates.[10]

Our review of all consumption values found that the billing analysis results were reasonable[11]. Because savings vary with temperature we also reviewed the amount of HVAC energy consumption estimated in each 8,760 hour temperature bin.

The section "Method – Heating and Cooling Savings Calculations" explains that we assumed cooling energy consumed is proportional to cooling degree days. We used this assumption to calculate the proportion of HVAC energy consumption[12] in each one-degree temperature bin. With known energy consumption (kWh) and known power (kW is a function of outdoor temperature) we estimate the hours of operation in each temperature bin to determine the ratio of hours of operation to total hours per year at each temperature. We compared estimated coincidence factors to end-use metering conducted at a sample of 24 air conditioner and 23 heat pump sites. Figure 4 shows an example of the average estimated coincidence factor of metered participants alongside the modeled coincidence factor.

Figure 4. Coincidence Factor Comparison: Estimated from Billing Analysis and End-Use Metering



[10] The analysis is based on energy consumption and physical limits of the HVAC equipment specification data. If the billing analysis overestimates HVAC consumption for one participant and underestimates consumption for another, the analysis has bias that underestimates savings. For example, as HVAC heating energy consumption increases we assume a larger portion of consumption is electric resistance heat, which has no savings. In cooling mode, we might assume more high-stage operation (low savings) than is realistic if HVAC consumption load is high. Conversely, there is no physical limit if HVAC consumption estimate is low. We mitigate bias by averaging HVAC consumption estimates.

[11] Cadmus has performed extensive residential HVAC metering across the country. In total we have performed long-term (full season) metering of more than 1,000 central HVAC systems.

[12] Energy consumption determined through billing analysis

To estimate heating and cooling consumption in normal temperature bins, we followed the methods described in the section above. Table 8 shows the average monthly and total yearly savings for central air conditioners and heat pumps for each mode of operation (cooling mode for ACs and HPs, heating mode for HPs, savings when the air conditioner furnace fan runs in heating mode, and circulation mode).

Table 8. Monthly Average kWh Savings by System Type and Mode of Operation

	Central Air Conditioner Savings			Central Heat Pump Savings			
	ECM (Heating and Circulation Mode)	Cooling	Total	ECM (Circulation Mode)	Heating	Cooling	Total
January	40	-	40.2	14.3	122.59	-	136.9
February	37	-	37.3	14.3	108.87	-	123.1
March	30	-	29.8	14.3	73.66	-	87.9
April	19	16	34.5	14.3	22.42	13	49.4
May	16	40	55.9	14.3	8.33	33	55.3
June	15	73	87.5	14.3	3.10	60	76.9
July	14	171	185.6	14.3	-	140	154.8
August	14	127	141.2	14.3	-	104	118.3
September	16	60	75.8	14.3	8.79	49	72.0
October	21	14	35.4	14.3	32.50	12	58.4
November	25	-	25.0	14.3	50.75	-	65.0
December	36	-	35.6	14.3	100.87	-	115.1
Total	**284**	**500**	**783.8**	**171**	**532**	**410.1**	**1113.2**

Table 9 summarizes the average savings for the program by system type and mode of operation and shows total program gross energy (kWh) savings for central air conditioners and heat pumps evaluated by the Cadmus Team[13].

Table 9. Heating and Cooling Savings for Air Conditioners and Heat Pumps

	Average Savings per System (kWh)	Number of Units	Total Savings (kWh)
Air Conditioner Heat (ECM savings)	112	5,201	4,076,392
Air Conditioner Cool	500		
ECM Circulation Mode	171		
Air Conditioner Total Savings	**784**		
Heat Pump Heat	532	2,304	2,564,822
Heat Pump Cool	410		
ECM Circulation Mode	171		
Heat Pump Total Savings	**1,113**		
Total Savings	**948**	**7,505**	**6,641,214**

[13] 7% of systems were precluded from analysis because billing analysis results were unreliable. The team used the average savings per system to determine savings for all 7,505 participants (see Table 1).

Table 10 shows the average demand savings values for central air conditioners and for central heat pumps. The demand savings values were estimated with DSMore using the monthly kWh savings values in Table 8. Demand savings values do not include transmission line losses.

Table 10. Per-Unit Demand Savings Estimated by DSMore Simulation Tool

Measure	Annual Non-Coincident kW	Summer Coincident kW	Winter Coincident kW
Smart $aver Central Air Conditioner	0.501	0.463	0.104
Smart $aver Central Heat Pump	0.417	0.386	0.354

Net-to-Gross

This section describes the method, analysis, and findings TecMarket Used in 2014[14] for determining the net to gross (NTG) for the Residential Smart $aver HVAC program, using the following formula:

$$NTG = (1 - Freeridership) + Customer\ Spillover$$

We calculated the freeridership and spillover estimates based on responses from participating customer surveys. Duke Energy reviewed the survey and algorithms and provided input, helping to ensure the approach accounted for important program design elements.

Freeridership

TecMarket Works fielded a short survey with HVAC vendor allies to estimate freeridership. Participant surveys are not used in this analysis because many customers did not know that their purchase price was reduced via the Duke Energy program because the incentive was applied through participating dealers.

Method

TecMarket Works established freeridership using a primary gateway question that could be directed, depending on the response, to a follow-up question about the influence of the Smart $aver rebate. The gateway question asked vendors what their customer's behavior would have been if the Smart $aver rebate had not been available.

Gateway Question (A): ***Of the Energy Efficient equipment that was rebated through the program, what percentage of those customers do you think would have still gone with an energy efficient model if the Duke Energy rebate were not available?***

To determine this gateway value, and to check consistency, we asked vendors to rate the level of influence the Smart $aver rebate may have had on choices made by the customers.

Follow-up Question (B): ***Using a scale of 1 to 10, where 1 means not at all influential and 10 means very influential, how important would you say the rebate is to your customers' decision when considering all the various factors that a customer typically contemplates prior to making a purchase from your company?***

We turned influence ratings on a 10-point scale into percentages for use in the NTG formula, based on the conversion values shown in Table 11.

[14] This report section was written in 2014 by TecMarket Works before TecMarket Works was acquired by Cadmus, and reviewed by Cadmus in 2015.

Table 11. Percentages Used for Net Calculations Based on Vendor Influence Ratings

Influence Rating Score	Equivalent Percentage Value
10	100%
9	90%
8	80%
7	70%
6	60%
5	40%
4	30%
3	20%
2	10%
1	0%

Table 12 shows the mean and median responses to the gateway (column A) and follow-up (column B) questions; for each question, 70 out of 79 surveyed trade allies gave responses that could be scored for the first question. The follow-up question has been converted from 10-point ratings into percentage scores (as shown in Table 11). 74 out of 79 surveyed trade allies gave responses that could be scored for the follow-up question.

Table 12. Vendor Responses Used to Estimate Freeridership

	Gateway Question (A) (N=70)	Follow-Up Question (B) (N=74)
Mean percentage	78.5%	56.%
Median percentage	90.0%	70.0%
Minimum	0%	0%
Maximum	100%	100%

Results

The formula for estimating freeridership is shown below, where A and B represent responses to the two survey questions and factor represents a coefficient that accounts for a level of uncertainty around the establishment of a NTG ratio.

Freeridership = A * (1 – (B * Factor))

Freeridership is calculated separately for every vendor who answered both questions,[15] and the average of these individual scores provides the overall freeridership estimate for the program. The value of factor is set to 1.0, assuming vendors are not overestimating or underestimating the effect of the program; to less than 1.0, depending on how much vendors overestimate the program's effect; and to

[15] Each of the freeridership questions was answered individually by 70 out of 79 surveyed trade allies in Kentucky and Ohio; however, only 67 out of 79 survey respondents answered both questions. Since both questions are required to compute a freeridership score, the twelve respondents who did not answer both questions are withheld from calculations and the valid N for freeridership computations is 67 respondents.

greater than 1.0 if vendors are underestimating the program's effect. In this case, however, we do not know the true value of the factor, so we calculated overall freeridership rates based on five different levels of factor influence (150%, 125%, 100%, 75% and 50%), which we then averaged to estimate freeridership for the residential Smart $aver HVAC program. Using this approach, we estimated a 37.6% NTG factor to account for freeridership, as shown in Table 13.

Table 13. Freeridership Estimates Based on Five Scenarios

Factor Value	Calculated Freeridership (N=67)
150%	22.2%
125%	26.5%
100%	35.3%
75%	46.4%
50%	57.5%
Average of 5 scenarios above	**37.6%**

Spillover

The Residential Smart $aver HVAC program involved large single-unit residential installations. For this reason, individual participant spillover for HVAC systems is assumed to be at or near zero. Although some customers installed more than one unit, in most cases these installations received a rebate from the program and were included in the program's energy savings calculations.

Calculated Net-To-Gross

The NTG ratio for this program is 0.624 and includes a downward adjustment in gross savings equal to the freeridership percentage, 37.6% of the gross savings. There is no adjustment for spillover savings for this program. Table 14 shows the gross and net heating and cooling savings for air conditioners and heat pumps evaluated by the Team. Table 15 shows the gross and net summer coincident demand savings for air conditioners and heat pumps evaluated by the Team.

Table 14. Duke Energy Ohio and Kentucky Net Heating and Cooling Savings for Air Conditioners and Heat Pumps

Program Component	Average Gross Savings per System (kWh)	Units	Total Gross Savings (kWh)	Total Net Savings (kWh)
Air Conditioner Heat (ECM savings)	112	**5,201**	4,076,392	2,543,669
Air Conditioner Cool	500			
ECM Circulation Mode	171			
Air Conditioner Total	**784**			
Heat Pump Heat	532	**2,304**	2,564,822	1,600,449
Heat Pump Cool	410			
ECM Circulation Mode	171			
Heat Pump Total	**1,113**			
Total Savings		**7,505**	**6,641,214**	**4,144,118**

Table 15. Duke Energy Ohio and Kentucky Net Heating and Cooling Summer Coincident Demand Savings for Air Conditioners and Heat Pumps

Measure	Average Gross Savings per System (kW)	Units	Total Gross Savings (kW)	Total Net Savings (kW)
Smart $aver Central Air Conditioner	0.463	5,201	2,406	1,502
Smart $aver Central Heat Pump	0.386	2,304	889	555
Total Savings		**7,505**	**3,295**	**2,056**