CADMUS

MEMORANDUM

To: Laureen Welikson and Greg Lovett; Ameren Missouri

From: Shannon Donohue, John Walczyk, Jeremy Eckstein, Sara Wist, Brian Evans, and Jane Colby; Cadmus

Subject: PY16 Heating and Cooling Mid-Year Preliminary Per-Unit Savings Estimates

Date: December 2, 2016

This memo outlines the methodology and results of Cadmus' review of the potential per-unit savings for energy efficiency measures rebated through the program year 2016 (PY16) Ameren Missouri Heating and Cooling Program. The PY16 measures include:

- Air-source heat pumps (ASHP)
- Central air conditioners (CAC)
- Concept 3 fans (ECM fan)
- Duel fuel heat pumps
- Ductless ASHPs
- Ground-source heat pumps (GSHP)

The 2016 Technical Reference Manual (TRM) has separate savings values for heat pump and CAC measures for replace on burnout, early retirement, and new construction applications. The heat pump measures also have baseline categories of whether they replace another heat pump or an electric resistance furnace. The ECM fan measures are categorized by whether they operate continuously or automatically.

Estimated Savings Results

Cadmus reviewed best practices for calculating energy savings for each measure type offered through the Heating and Cooling Program. Table 1 lists the TRM-based per-unit savings for each measure along with savings Cadmus calculated based on algorithms we developed in previous evaluations and based on the best information available. Values from Q1 are prior to a change in enforcement of the updated heat pump efficiency standards. For 2016 Q2 and beyond the values for Q2 should be used.

Table 1. PY16 TRM and Estimated Per-Unit Savings Summary

Measure Type	TRM Measure Name	Annual Electric Savings (kWh)		
		TRM Gross	Evaluated Gross 2016 Q1	Evaluated Gross 2016 Q2
Air Sourced	ASHP - SEER 15 ER Electric Resistance Furnace:	15,152	13,903	13,903

720 SW Washington Street
Suite 400
Portland, OR 97205
Voice: 503.467.7100
Fax: 503.228.3696

An Employee-Owned Company
www.cadmusgroup.com

Corporate Headquarters:
100 5th Avenue, Suite 100
Waltham, MA 02451
Voice: 617.673.7000
Fax: 617.673.7001

Measure Type	TRM Measure Name	Annual Electric Savings (kWh)		
		TRM Gross	Evaluated Gross 2016 Q1	Evaluated Gross 2016 Q2
Heat Pump (ASHP)	HVAC			
	ASHP - SEER 15 Early Replacement with ASHP: HVAC	4,983	4,862	4,862
	ASHP - SEER 15 Replace at Fail Electric Resistance Furnace: HVAC	13,977	11,584	11,562
	ASHP - SEER 15 Replace at Fail with ASHP: HVAC	1,521	1,462	860
	ASHP - SEER 16+ Early Replacement Electric Resistance Furnace: HVAC	16,633	16,448	16,448
	ASHP - SEER 16+ Early Replacement with ASHP: HVAC	6,500	6,487	6,487
	ASHP - SEER 16+ Replace at Fail Electric Resistance Furnace: HVAC	16,129	13,187	13,160
	ASHP - SEER 16+ Replace at Fail with ASHP: HVAC	1,845	2,456	1,770
Central Air Conditioner (CAC)	CAC - SEER 14 Early Replacement: HVAC	1,642	1,636	1,636
	CAC - SEER 14 Replace at Fail: HVAC	328	323	323
	CAC - SEER 15 Early Replacement: HVAC	1,925	1,927	1,927
	CAC - SEER 15 Replace at Fail: HVAC	384	377	377
	CAC - SEER 16+ Early Replacement: HVAC	1,925	1,929	1,929
	CAC - SEER 16+ Replace at Fail: HVAC	383	351	351
Concept 3 Fan (ECM Fan)	ECM Auto Fan Early Replacement: HVAC	648	794	794
	ECM Auto Fan Replace at Fail: HVAC	665	785	785
	ECM Continuous Fan Early Replacement: HVAC	3,489	3,289	3,289
	ECM Continuous Fan Replace at Fail: HVAC	3,489	3,289	3,289
Dual Fuel Heat Pump	Dual Fuel Heat Pump - SEER 15_SF: HVAC	1,348	1,219	370
	Dual Fuel Heat Pump - SEER 16_SF: HVAC	1,213	1,258	542
	Dual Fuel Heat Pump - SEER 17_SF: HVAC	1,530	1,908	1,037
	Dual Fuel Heat Pump - SEER 18_SF: HVAC	1,040	1,866	1,079
Ductless Heat Pump	Ductless ASHP Early Replacement: HVAC	3,686	4,594	4,594
	Ductless ASHP Early Replacement Electric Resistance: HVAC	5,725	7,465	7,465
	Ductless ASHP Electric Resistance Replace at Fail: HVAC	4,370	7,925	7,906
	Ductless ASHP Replace at Fail: HVAC	2,211	2,119	1,746
Ground Sourced Heat Pump (GSHP)	GSHP - SEER 14+ Early Replacement Elec Resist Furnace: HVAC	28,485	27,201	27,201
	GSHP - SEER 14+ Replace Electric Resistance Furnace: HVAC	27,208	22,900	22,840
	GSHP SEER 14+ Early Replacement ASHP with GSHP: HVAC	6,322	12,667	12,667
	GSHP - 23 EER Early Replacement: HVAC	4,717	8,607	8,607

Measure Type	TRM Measure Name	Annual Electric Savings (kWh)		
		TRM Gross	Evaluated Gross 2016 Q1	Evaluated Gross 2016 Q2
	GSHP - 23 EER Replace at Fail	2,702	3,668	3,607

The above evaluated gross savings were calculated using the average installed system size and efficiency from the Ameren Missouri 2016 quarterly data. These data are shown below in Table 2.

Table 2. Average Installed Systems

TRM Measure Name	Average Tonnage Installed	Average SEER Installed	Average HSPF Installed	Average EER Installed	Average COP Installed
ASHP - SEER 15 ER Electric Resistance Furnace: HVAC	2.85	15.12	8.72	-	-
ASHP - SEER 15 Early Replacement with ASHP: HVAC	2.99	15.11	8.68	-	-
ASHP - SEER 15 Replace at Fail Electric Resistance Furnace: HVAC	2.67	15.18	8.47	-	-
ASHP - SEER 15 Replace at Fail with ASHP: HVAC	3.02	15.11	8.73	-	-
ASHP - SEER 16+ Early Replacement Electric Resistance Furnace: HVAC	3.19	16.87	9.46	-	-
ASHP - SEER 16+ Early Replacement with ASHP: HVAC	3.37	16.89	9.46	-	-
ASHP - SEER 16+ Replace at Fail Electric Resistance Furnace: HVAC	2.82	17.42	9.54	-	-
ASHP - SEER 16+ Replace at Fail with ASHP: HVAC	3.43	17.20	9.47	-	-
CAC - SEER 14 Early Replacement: HVAC	3.02	14.15	-	-	-
CAC - SEER 14 Replace at Fail: HVAC	2.97	14.21	-	-	-
CAC - SEER 15 Early Replacement: HVAC	3.32	15.13	-	-	-
CAC - SEER 15 Replace at Fail: HVAC	3.26	15.15	-	-	-
CAC - SEER 16+ Early Replacement: HVAC	3.08	16.36	-	-	-
CAC - SEER 16+ Replace at Fail: HVAC	2.81	16.34	-	-	-
Dual Fuel Heat Pump - SEER 15_SF: HVAC	4.00	15.29	8.75	-	-
Dual Fuel Heat Pump - SEER 16_SF: HVAC	3.25	16.31	9.25	-	-
Dual Fuel Heat Pump - SEER 17_SF: HVAC	3.78	17.67	10.08	-	-
Dual Fuel Heat Pump - SEER 18_SF: HVAC	3.35	18.25	10.50	-	-
Ductless ASHP Early Replacement: HVAC	1.88	20.46	11.16	-	-

Ductless ASHP Early Replacement Electric Resistance: HVAC	1.27	23.24	11.60	-	-
Ductless ASHP Electric Resistance Replace at Fail: HVAC	1.55	22.57	11.38	-	-
Ductless ASHP Replace at Fail: HVAC	1.83	22.37	11.23	-	-
GSHP - 23 EER Early Replacement: HVAC	4.42	-	-	27.03	4.39
GSHP - 23 EER Replace at Fail	4.67	-	-	23.63	4.22
GSHP - SEER 14+ Early Replacement Elec Resist Furnace: HVAC	4.17	-	-	27.70	4.42
GSHP - SEER 14+ Replace Electric Resistance Furnace: HVAC	4.05	-	-	26.87	4.38
GSHP SEER 14+ Early Replacement ASHP with GSHP: HVAC	3.58	-	-	32.15	4.64

Source: Ameren Heating and Cooling program tracking data Program Year 2016 Q1-2

Measure-Specific Per-Unit Savings

Cadmus engineers reviewed the 2016 TRM deemed per-unit savings for all program measures. We then compared these assumptions to the latest data available to develop estimated per-unit savings values. The following sections outline the estimated per-unit savings for each measure, along with the algorithm and inputs we used.

Air Sourced Heat Pumps

Cadmus estimated per-unit savings for ASHPs using the following algorithm:

$$\Delta kWh_{ASHP} = Installed\ Tons \times \left(\frac{Metered\ kWh\ Savings\ Cooling \times Installed\ SEER}{Metered\ SEER\ Cooling\ \times Metered\ Tons\ Cooling} + 12 \times Heating\ EFLH \times \left(\frac{1}{Baseline\ HSPF} - \frac{1}{Installed\ HSPF} \right) \right)$$

Where:

Installed Tons = The output capacity of installed ASHP (tons)

Metered kWh Savings Cooling = Average cooling savings from PY13 metering (kWh)

Installed SEER = The SEER rating of the installed ASHP (Btu/Wh)

Metered SEER Cooling = The SEER rating of the PY13 metered cooling systems (Btu/Wh)

Metered Tons Cooling = The output capacity of the PY13 metered cooling systems (tons)

12 = Conversion constant from tons to kBtu/hr

Heating EFLH = Equivalent full-load heating hours

Baseline HSPF = HSPF value of the baseline system

Installed HSPF = HSPF value of the installed system

Table 3 and shows the values for the variables that Cadmus used to estimate savings in PY16 Q1 and PY16 Q2 for ASHPs. Changes from Q1 to Q2 reflect changes in federal standards.

Table 3. Air-Source Heat Pump PY16 Savings Variables

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source
Metered kWh Savings Cooling	ASHP Early Replacement with ASHP 16+	1,805.00	1,805.00	PY13 metering study*
	ASHP Early Replacement with ASHP SEER 15ER	1,805.00	1,805.00	PY13 metering study*
	ASHP Replace at Fail with ASHP 16+	360.00	334.29	PY13 metering study* updated with new federal standard
	ASHP Replace at Fail with ASHP SEER 15	360.00	334.29	PY13 metering study* updated with new federal standard
	ASHP SEER 15 Early Replacement Electric Resistance Furnace	1,805.00	1,805.00	PY13 metering study*
	ASHP SEER 15 Replace at Fail Electric Resistance Furnace	360.00	334.29	PY13 metering study* updated with new federal standard
	ASHP SEER 15 Replace at Fail Electric Resistance Furnace (New Construction)	360.00	334.29	PY13 metering study* updated with new federal standard
	ASHP SEER 16+ Early Replacement Electric Resistance Furnace	1,805.00	1,805.00	PY13 metering study*
	ASHP SEER 16+ Replace at Fail Electric Resistance Furnace	360.00	334.29	PY13 metering study* updated with new federal standard
Metered SEER Cooling	All ASHP	15.20	15.20	PY13 metering study*
Metered Tons Cooling	All ASHP	3.10	3.10	PY13 metering study*
Heating EFLH	All ASHP	2,009.00	2,009.00	ENERGY STAR Heat Pump Calculator**
Baseline HSPF	ASHP Early Replacement with ASHP 16+	6.30	6.30	Cadmus data: HSPF = 0.2675 x SEER + 4.3475
	ASHP Early Replacement with ASHP SEER 15	6.30	6.30	Cadmus data: HSPF = 0.2675 x SEER + 4.3475
	ASHP Replace at Fail with ASHP 16+	7.70	8.20	Federal standard
	ASHP Replace at Fail with ASHP SEER 15	7.70	8.20	Federal standard
	ASHP SEER 15 Early Replacement Electric Resistance Furnace	3.41	3.41	Electric heating efficiency

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source
	ASHP SEER 15 Replace at Fail Electric Resistance Furnace	3.41	3.41	Electric heating efficiency
	ASHP SEER 15 Replace at Fail Electric Resistance Furnace (New Construction)	7.70	8.20	Federal standard
	ASHP SEER 16+ Early Replacement Electric Resistance Furnace	3.41	3.41	Electric heating efficiency
	ASHP SEER 16+ Replace at Fail Electric Resistance Furnace	3.41	3.41	Electric heating efficiency

* The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

** U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for 20 ENERGY STAR Qualified Air Source Heat Pump(s)." Excel file. Last updated April 2009. Available online: https://essearch.energystar.gov/search?utf8=%E2%9C%93&sc=0&query=ashp%20sav%20calc&m=&affiliate=www.energystar.gov&commit=Search

Energy savings from ASHPs are significantly dependent on the amount of energy saved during the heating season. This is primarily driven by the current equivalent full-load hour (EFLH) value for heating provided by the ENERGY STAR calculator. Cadmus is researching this EFLH value through heat pump monitoring and hourly load disaggregation. We recently performed monthly billing analysis[1] on a sample of 505 heat pump participants in PY16 and found that the current EFLH value may over-state the heating energy usage for early retirement measures and electric resistance baseline heating systems. The billing analysis results indicate a significant variance between the actual amount of energy used by ASHPs and the amount predicted by the TRM (2,009 heating EFLH). While some of the variance is likely due to analysis error and other uncontrolled factors, Cadmus can draw several conclusion from these data:

- Heating EFLH is overstated in the ENERGY STAR calculator
- Heating EFLH values should be determined separately for systems with replaced electric resistance
- Further research is required to determine the best EFLH values for systems with replaced electric resistance

[1] The Cadmus Group. *Overview of Participant Billing Analysis Ameren UE HVAC.* September 2016.

Central Air Conditioners

Cadmus estimated per-unit savings for CACs using the following algorithm:

$$\Delta kWh_{CAC} = \frac{Metered\ kWh\ Savings\ Cooling * Installed\ Tons * Installed\ SEER}{Metered\ SEER\ Cooling\ \times Metered\ Tons\ Cooling}$$

Where:

Metered kWh Savings Cooling = Average cooling savings from PY13 metering (kWh)

Installed tons = The output capacity of installed ASHP (tons)

Installed SEER = The SEER rating of the installed ASHP (Btu/Wh)

Metered SEER Cooling = The SEER rating of the PY13 metered cooling systems (Btu/Wh)

Metered Tons Cooling = The output capacity of the PY13 metered cooling systems (tons)

Table 4 shows the values for the variables that Cadmus used to estimate savings in PY16 for CACs.

Table 4. Central Air Conditioner PY16 Savings Variables

Parameter	Ameren Missouri Catalog Name	PY16	Source
Metered kWh Savings Cooling	CAC SEER 14 Early Replacement	1805.00	PY13 metering study*
	CAC SEER 14 Replace at Fail	360.00	PY13 metering study*
	CAC SEER 15 Early Replacement	1805.00	PY13 metering study*
	CAC SEER 15 Replace at Fail	360.00	PY13 metering study*
	CAC SEER 16+ Early Replacement	1805.00	PY13 metering study*
	CAC SEER 16+ Replace at Fail	360.00	PY13 metering study*
Metered SEER Cooling	All CACs	15.20	PY13 metering study*
Metered Tons Cooling	All CACs	3.10	PY13 metering study*

* The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

Concept 3 Fans

Cadmus estimated per-unit ECM fan savings using the following algorithms:

$$\Delta kWh_{Auto\ With\ CAC} = \Bigg((\text{Wisconsin Cooling Savings kWh/year} + \text{Cooling Savings All Systems}) \times \frac{Cooling\ EFLH}{Wisconsin\ Cooling\ EFLH} + \left(\text{Wisconsin Heating Savings kWh/year} \times \frac{Heating\ EFLH}{Wisconsin\ Heating\ EFLH}\right)\Bigg) + \text{Wisconsin Circulation Savings kWh/year} \times \%\ \text{of Circulation Used} - \text{Standby losses}$$

$$\Delta kWh_{Auto\ Without\ CAC} = \Bigg((\text{Cooling Savings All Systems}) \times \frac{Cooling\ EFLH}{Wisconsin\ Cooling\ EFLH} + \left(\text{Wisconsin Heating Savings kWh/year} \times \frac{Heating\ EFLH}{Wisconsin\ Heating\ EFLH}\right)\Bigg) + \text{Wisconsin Circulation Savings kWh/year} \times \%\ \text{of Circulation Used} - \text{Standby losses}$$

$$\Delta kWh_{Continous\ Fan} = \Bigg((\text{Wisconsin Cooling Savings kWh/year} + \text{Cooling Savings All System}) \frac{Cooling\ EFLH}{Wisconsin\ Cooling\ EFLH} \times \text{Wisconsin Heating Savings kWh/year} \times \frac{Heating\ EFLH}{Wisconsin\ Heating\ EFLH}\Bigg) + \text{Wisconsin Circulation Savings kWh/year} - \text{Standby losses}$$

Where:

Wisconsin Cooling Savings kWh/year = ECM fan savings during the cooling season in Wisconsin (kWh/year)

Cooling Savings All Systems = Cooling savings for ECMs not installed with program CAC or ASHP (kWh/year)

Cooling EFLH = Equivalent full-load cooling hours in Missouri

Wisconsin Cooling EFLH = Equivalent full-load cooling hours in Wisconsin

Wisconsin Heating Savings kWh/year = ECM fan savings during heating season in Wisconsin (kWh/year)

Heating EFLH = Equivalent full load heating hours in Missouri

Wisconsin Heating EFLH = Equivalent full load heating hours in Wisconsin

Wisconsin Circulation Savings kWh/year = ECM fan savings while the fan is operating in circulation mode

% of Circulation Used = Percentage of time ECMs operate in circulation mode for installations designated "auto mode"

Standby losses = Standby losses from ECM controls (kWh/year)

Cadmus used a Wisconsin study[2] to estimate savings for ECM fans installed through the Ameren Missouri Heating and Cooling Program. ECM fans are able to reduce fan speed and power to save energy in three ways:

- Cooling mode savings
- Heating mode savings
- Circulation mode savings

Cadmus calculated savings in heating mode using savings estimates from the Wisconsin study. We adjusted savings by estimating the proportion of heating runtimes in Wisconsin to heating runtimes in Missouri. Table 5 shows the values of the variables used by Cadmus to calculate savings in PY16 for ECMs.

Table 5. ECM Fans PY16 Savings Variables

Parameter	PY16	Source
Wisconsin Cooling Savings kWh/year	70.00	Secondary source;* however, Cadmus weighted this values to more accurately reflect the actual number of fans operated in continuous mode based on PY13 meter data
Cooling Savings All Systems	25.00	Secondary source*
Wisconsin Cooling EFLH	542.50	EPA 2002/ENERGY STAR Calculator**
Wisconsin Heating Savings kWh/year	400.00	Secondary source*
Wisconsin Heating EFLH	2,545.25	EPA 2002/ENERGY STAR Calculator**
Wisconsin Circulation Savings kWh/year	2,960.00	Secondary source;* however, Cadmus weighted this value to more accurately reflect the actual number of fans operated in continuous mode based on PY13 meter data
% of Circulation Used	10%	PY13 meter data***

[2] Energy Center of Wisconsin. *Electricity Use by New Furnaces, A Wisconsin Field Study.* pp. 41. October 2003. Available online: http://www.proctoreng.com/dnld/WIDOE2013.pdf

Parameter	PY16	Source
Standby losses	30	Secondary source;* however, Cadmus weighted this values to more accurately reflect the actual number of fans operated in continuous mode based on PY13 meter data
Heating EFLH	2,009.00	EPA 2002/ENERGY STAR Calculator**
Cooling EFLH	1,215.00	EPA 2002/ENERGY STAR Calculator**

* Energy Center of Wisconsin. *Electricity Use by New Furnaces, A Wisconsin Field Study.* pp. 41. October 2003. Available online: http://www.proctoreng.com/dnld/WIDOE2013.pdf

** U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for 20 ENERGY STAR Qualified Air Source Heat Pump(s)." Excel file. Last updated April 2009. Available online: https://essearch.energystar.gov/search?utf8=%E2%9C%93&sc=0&query=ashp%20sav%20calc&m=&affiliate=www.energystar.gov&commit=Search

*** The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

Dual Fuel Heat Pumps

Cadmus estimated per-unit dual fuel heat pump savings using the following algorithm:

$$\Delta kWh_{DFHP} = Installed\ Tons \times \left(\frac{Metered\ kWh\ Savings\ Cooling \times Installed\ SEER}{Metered\ SEER\ Cooling\ \times Metered\ Tons\ Cooling} + 12 \times Heating\ EFLH \times \left(\frac{1}{Baseline\ HSPF} - \frac{1}{Installed\ HSPF} \right) \right)$$

Where:

Installed Tons = The output capacity of installed dual fuel heat pumps (tons)

Metered kWh Savings Cooling = Average cooling savings from PY13 metering (kWh)

Installed SEER = The SEER rating of the installed dual fuel heat pump (Btu/Wh)

Metered SEER Cooling = The SEER rating of the PY13 metered cooling systems (Btu/Wh)

Metered Tons Cooling = The output capacity of the PY13 metered cooling systems (tons)

12 = Conversion constant from tons to kBtu/hr

Heating EFLH = Equivalent full-load heating hours

Baseline HSPF = HSPF value of the baseline system

Installed HSPF = HSPF value of the installed system

Table 6 shows the values for the variables that Cadmus used to estimate savings in PY16 Q1 and PY16 Q2 for dual fuel heat pumps. Changes from Q1 to Q2 result from changes in federal standards.

Table 6. Dual Fuel Heat Pump PY16 Savings Assumptions

Parameter	PY16 Q1	PY16 Q2	Source
Metered kWh Savings Cooling	360.00	334.00	PY13 metering study* updated with new federal standard in Q2
Metered SEER Cooling	15.20	15.20	PY13 metering study*
Metered Tons Cooling	3.10	3.10	PY13 metering study*
Heating EFLH	1,004.50	1004.50	Assumption. Cadmus reviewed tonnage, and it does not seem that systems are sized atypically. A small size would indicate longer runtimes. We assumed that 50% of capacity is provided by the heat pump, and 50% by the furnace.
Baseline HSPF	7.70	8.20	Federal standard

* The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

Ductless Air-Source Heat Pumps

Cadmus estimated per-unit ductless ASHP savings using the following algorithm:

$$\Delta kWh = Installed\ Tons \times \left(\frac{Metered\ kWh\ Savings\ Cooling \times Installed\ SEER}{Metered\ SEER\ Cooling \times Metered\ Tons\ Cooling} + 12 \times Heating\ EFLH \times \left(\frac{1}{Baseline\ HSPF} - \frac{1}{Installed\ HSPF} \right) \right)$$

Where:

Installed Tons =The output capacity of installed ductless ASHP (tons)

Metered kWh Savings Cooling = Average cooling savings from PY13 metering (kWh)

Installed SEER = The SEER rating of the installed ductless ASHP (Btu/Wh)

Metered SEER Cooling = The SEER rating of the PY13 metered cooling systems (Btu/Wh)

Metered Tons Cooling = The output capacity of the PY13 metered cooling systems (tons)

12 = Conversion constant from tons to kBtu/hour

Heating EFLH = Equivalent full-load heating hours

Baseline HSPF = HSPF value of the baseline system

Installed HSPF = HSPF value of the installed system

Table 7 shows the values for the variables that Cadmus used to estimate savings in PY16 Q1 and PY16 Q2 for Ductless ASHPs.

Table 7. Ductless ASHP PY16 Savings Assumptions

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source
Metered kWh Cooling	Ductless ASHP Early Replacement	1,805.00	1,805.00	PY13 metering study*
	Ductless ASHP Early Retirement Electric Resistance	1,805.00	1,805.00	PY13 metering study*
	Ductless ASHP Replace at Fail Electric Resistance	360.00	334.29	PY13 metering study* updated with new federal standard
	Ductless ASHP Replace at Fail	360.00	334.29	PY13 metering study* updated with new federal standard
Metered SEER Cooling	All Ductless ASHP	15.20	15.20	PY13 metering study*
Metered Tons Cooling	All Ductless ASHP	3.10	3.10	PY13 metering study*
Heating EFLH	All Ductless ASHP	2,009.00	2,009.00	EPA 2002/ENERGY STAR Heat Pump Calculator**
Baseline HSPF	Ductless ASHP Early Retirement	6.30	6.30	Cadmus data: HSPF = 0.2675 * SEER + 4.3475
	Ductless ASHP Early Retirement Electric Resistance	3.41	3.41	Electric heating efficiency
	Ductless ASHP Replace at Fail Electric Resistance	3.41	3.41	Electric heating efficiency
	Ductless ASHP Replace at Fail	7.70	8.20	Federal standard

* The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

** U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for 20 ENERGY STAR Qualified Air Source Heat Pump(s)." Excel file. Last updated April 2009. Available online: https://essearch.energystar.gov/search?utf8=%E2%9C%93&sc=0&query=ashp%20sav%20calc&m=&affiliate=www.energystar.gov&commit=Search

Ground Sourced Heat Pumps

Cadmus estimated per-unit GSHP savings using the following algorithm:

$$\Delta kWh = Installed\ Tons \times \left(\frac{Metered\ kWh\ Savings\ Cooling \times Installed\ EER}{Metered\ SEER\ Cooling \times Metered\ Tons\ Cooling} + 12 \times Heating\ EFLH \times \left(\frac{1}{Baseline\ HSPF} - \frac{1}{Installed\ HSPF} \right) \right)$$

Where:

Installed Tons = The output capacity of installed ASHP (tons)

Metered kWh Savings Cooling = Average cooling savings from PY13 metering (kWh)

Installed EER = The EER rating of the installed GSHP (Btu/Wh)

Metered SEER Cooling = The SEER rating of the PY13 metered cooling systems (Btu/Wh)

Metered Tons Cooling = The output capacity of the PY13 metered cooling systems (tons)

12 = Conversion constant from tons to kBtu/hour

Heating EFLH = Equivalent full-load heating hours

Baseline HSPF = The coefficient of performance (COP) value of the baseline system converted to HSPF (COP/3.412)

Installed HSPF = The COP value of the installed system converted to HSPF (COP/3.412)

Table 8 shows the values for the variables that Cadmus used to estimate savings in PY16 Q1 and PY16 Q2 for GSHPs. Changes from Q1 to Q2 reflect new federal standards.

Table 8. Ground Sourced Heat Pump PY16 Savings Assumptions

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source
Metered kWh Savings Cooling	GSHP - 23 EER Early Replacement	1,805.00	1,805.00	PY13 metering study*
	GSHP - 23 EER Replace at Fail	360.00	334.29	PY13 metering study* updated with new federal standard
	GSHP SEER 14+ Early Replacement ASHP with GSHP Electric Resistance	1,805.00	1,805.00	PY13 metering study*
	GSHP SEER 14+ Electric Resistance Furnace Early Replacement	1,805.00	1,805.00	PY13 metering study*
	GSHP SEER 14+ Replace at Fail Electric Resistance Furnace	360.00	334.29	PY13 metering study* updated with new federal standard
Metered SEER Cooling	All GSHP	15.20	15.20	PY13 metering study*
Metered Tons Cooling	All GSHP	3.10	3.10	PY13 metering study*
Heating EFLH	All GSHP	2,009.00	2,009.00	EPA 2002/ENERGY STAR Heat Pump Calculator**
Baseline HSPF	GSHP - 23 EER Early Replacement	9.55	9.55	ICF International*** research on installed system types and typical baseline of removed and failed GSHP. Assuming ground loop heat exchange.
	GSHP - 23 EER Replace at	10.58	10.58	ICF International*** research on installed

Parameter	Ameren Missouri Catalog Name	PY16 Q1	PY16 Q2	Source
	Fail			system types and typical baseline of removed and failed GSHP. Assuming ground loop heat exchange.
	GSHP SEER 14+ Early Replacement ASHP with GSHP Electric Resistance	7.70	6.30	ICF International*** research on installed system types and typical baseline of removed and failed GSHP. Assuming ground loop heat exchange.
	GSHP SEER 14+ Electric Resistance Furnace Early Replacement	3.41	3.41	Electric resistance efficiency
	GSHP SEER 14+ Replace at Fail Electric Resistance Furnace	3.41	3.41	Electric resistance efficiency

* The Cadmus Group and Nexant. *Ameren Missouri CoolSavers Impact and Process Evaluation: Program Year 2013*. pp. 40. May 15, 2014. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935842419

** U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for 20 ENERGY STAR Qualified Air Source Heat Pump(s)." Excel file. Last updated April 2009. Available online: https://essearch.energystar.gov/search?utf8=%E2%9C%93&sc=0&query=ashp%20sav%20calc&m=&affiliate=www.energystar.gov&commit=Search

*** Email from M Cano to J Berg, J Walczyk, L Wilkson, M Gregory, L Brouk; "RE: Information On GSHP". Sent November 26, 2014