CADMUS

MEMORANDUM

To: Laureen Welikson and Greg Lovett; Ameren Missouri

From: Jane Colby, Sara Wist, and Trent Hardman; Cadmus

Subject: PY16 Energy Efficiency Kits Program: TRM Gross Savings

Date: November 30, 2016

Cadmus compared Ameren Missouri's deemed per-unit savings to our current estimates of measure-specific gross savings for the following measures offered in the Energy Efficiency Kits Program in program year 2016 (PY16):

- Energy-efficient showerhead
- Energy-efficient faucet aerator (kitchen)
- Energy-efficient faucet aerator (bathroom)
- Light emitting diode (LED) bulbs (9-watt ENERGY STAR® LEDs with 800 lumen output)
- Pipe wrap
- Furnace filter alarm

There are two types of kits each with their own delivery channel: school kits delivered through school teachers to their students and multifamily kits delivered by property manager to their tenants. The school-based kits contain two additional measures: shower timers and LED night lights. If Cadmus evaluates these energy efficiency measures, we will provide the corresponding savings algorithms in a separate memo.

Measure-Specific Gross Savings Methodology

Cadmus estimated gross savings for most program measures using the engineering algorithms established in the Energy Efficiency Kits Evaluation Plan[1]; however, for the furnace filter alarm, we developed a new algorithm. We then compared the deemed per-unit savings as provided in Ameren Missouri's Technical Reference Manual (TRM)[2] and available through the web-based interface to our own gross savings estimates. The TRM only provides deemed per-unit savings values, with no inputs or assumptions that were used to develop these estimates.

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1 Cadmus. "Energy Efficiency Kits Evaluation Plan." August 2016.

2 State of Missouri. "In the Matter of Union Electric Company d/b/a Ameren Missouri's 2nd Filing to Implement Regulatory Changes in Furtherance of Energy Efficiency as Allowed by MEEIA." File No. EO-2015-0055. February 5, 2016. Refer to Appendix F.

The calculations in this memo are per-unit savings estimates that do not include adjustments for the installation rate of kit items or for saturations of applicable electric heating and cooling equipment. Cadmus will obtain values for each of these adjustments from PY16 surveys, and will then update total gross savings as appropriate.

Estimated Savings Results

The TRM per-unit savings and gross per-unit savings estimates for the school-based kits and multifamily kits are presented in Table 1 and Table 2, respectively. The algorithms and assumptions for these estimated per-unit savings values are presented in subsequent discussion and tables.

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

Measure	TRM Per-Unit Savings (kWh/yr)	Cadmus Estimated Per-Unit Savings (kWh/yr)
Energy-Efficient Showerhead	218	181.6
Energy-Efficient Faucet Aerator (kitchen)	39	80
Energy-Efficient Faucet Aerator (bathroom)	39	22
Light Emitting Diode Bulb	25.8	38
Pipe Wrap (3 feet)	64.2*	78
Furnace Filter Alarm	110	195.8
* TRM value is 21.4 kWh/year for each foot of pipe wrap.		

Table 2. PY16 Multifamily Kits TRM and Estimated Per-Unit Savings Summary

Measure	TRM Per-Unit Savings (kWh/yr)	Cadmus Estimated Per-Unit Savings (kWh/yr)
Energy-Efficient Showerhead	218	206.2
Energy-Efficient Faucet Aerator (kitchen)	39	78
Energy-Efficient Faucet Aerator (bathroom)	39	22
Light Emitting Diode Bulb	25.8	38
Pipe Wrap (3 feet)	64.2*	68
Furnace Filter Alarm	110	195.8
* TRM value is 21.4 kWh/year for each foot of pipe wrap.		

Measure-Specific Per-Unit Savings

Cadmus engineers reviewed the TRM deemed per-unit savings for the program measures included in this memo. We then compared these values to other TRMs and recent studies to develop estimated per-unit savings values. The next sections outline Cadmus' estimated per-unit savings for each measure, along with the algorithm and inputs used.

Showerheads

We estimated energy-efficient showerhead savings using the following algorithm:

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = \frac{People \times Shower\ Time \times Days \times \%Days \times \Delta GPM \times (T_{SHOWER} - T_{IN}) \times C_P \times Den}{3{,}413 \times RE \times Showerheads}$$

Where:

People	=	The number of people taking showers (ppl/household)
Shower Time	=	The average shower length (min/shower)
Days	=	The number of days per year (day/yr)
%Days	=	The number of showers per day, per person (shower/day-ppl)
ΔGPM	=	The difference in rated gallons per minute for the base showerhead and the new showerhead (gal/min)
T_{SHOWER}	=	The average water temperature at the showerhead (°F)
T_{IN}	=	The average inlet water temperature (°F)
C_P	=	The specific heat of water (Btu/lb-°F)
Den	=	The water density (lbs/gal)
3,413	=	The conversion rate from Btu to kWh (Btu/kWh)
RE	=	The water heater's recovery efficiency
Showerheads	=	The number of showerheads used per home

Table 3 shows the inputs for the engineering algorithm used to determine saving from showerheads delivered through both the school kits and multifamily kits delivery channels. The inputs for number of people per home and number of showerheads per home differ between the two delivery channels. Cadmus will update these values based on PY16 survey data. Until we have these data, for the purposes of this memo, we used the single-family value from the previous evaluation as a placeholder value for the school kits delivery channel, and used the multifamily value from the previous evaluation for the multifamily kits delivery channel.

Table 3. Showerhead Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
People	2.67	PY14 Energy Kit Participant Survey (to be updated)	2.07	PY14 CommunitySavers Program Data (to be updated)
Shower Time	7.8	Secondary Source[1]	7.8	Secondary Source[1]
Days	365	Conversion Factor (day/yr)	365	Conversion Factor (day/yr)
%Days	0.6	Secondary Source[2]	0.6	Secondary Source[2]
ΔGPM	0.75	PY14 Program Data (to be	0.75	PY14 Program Data (to be

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
		updated)[3]		updated)[3]
T_{SHOWER}	105	Illinois TRM[4]	105	Illinois TRM[4]
T_{IN}	61.3	Ameren Missouri 2012 TRM[5]	61.3	Ameren Missouri 2012 TRM[5]
C_P	1	Specific Heat of Water (Btu/lb-°F)	1	Specific Heat of Water (Btu/lb-°F)
Den	8.33	Density (lb/gal)	8.33	Density (lb/gal)
3,413	3,413	Conversion Factor (Btu/kWh)	3,413	Conversion Factor (Btu/kWh)
RE	0.98	Secondary Source[6]	0.98	Secondary Source[6]
Showerheads	2.05	PY13 Program Data (to be updated)	1.4	PY13 Program Data (to be updated)

[1] Cadmus and Opinion Dynamics Evaluation Team. *Showerhead and Faucet Aerator Meter Study*. Memorandum prepared for Michigan Evaluation Working Group. pp 10. 2013.

[2] Ibid. pp. 11.

[3] The rated gallons per minute for the new showerhead will come from the PY16 program data and the rated gallons per minute for the base showerhead will come from the *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0.* pp. 184. 2016. Available Online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf

[4] Ibid. pp. 103.

[5] *Ameren Missouri 2012 Technical Resource Manual.* Appendix A. pp. 43. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483

[6] National Renewable Energy Laboratory, Building America Research. *Recovery efficiency for electric hot water heater.* Benchmark definition, pp. 12. 2009. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf

Kitchen Faucet Aerators

Cadmus plans to evaluate kitchen faucet aerators and bathroom faucet aerators separately each year from PY16 through PY18. We estimated per-unit savings for kitchen faucet aerators using the following algorithm:

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = \frac{People \times Faucet\ Time \times Days \times \Delta GPM \times (T_{FAUCET} - T_{IN}) \times C_P \times Den}{3{,}413 \times RE \times Number\ of\ Faucets}$$

Where:

People	=	The number of people using faucet aerators (people/household)
Faucet Time	=	The average length of faucet use per day (minutes/day)
Days	=	The number of days per year (day/yr)
ΔGPM	=	The difference in rated gallons per minute between the base unit and the new unit (gal/min)
ΔT	=	The temperature at the tap minus the temperature at the water main

T_{FAUCET} = The average water temperature out of the faucet (°F)

T_{IN} = The average inlet water temperature (°F)

C_P = The specific water heat (Btu/lb-°F)

Den = The water density (lb/gal)

3,413 = The conversion rate from Btu to kWh (Btu/kWh)

RE = The water heater's recovery efficiency

Number of faucets = The number of used faucets per home

Table 4 shows the inputs for the engineering algorithm used to determine savings from kitchen faucet aerators delivered through both the school kits and multifamily kits delivery channels. The inputs for number of people per home and number of faucets per home differ between the two delivery channels. Cadmus will update these values based on PY16 survey data. Until we have these data, for the purposes of this memo, we used the single-family value from the previous evaluation as a placeholder value for the school kits delivery channel, and used the multifamily value from the previous evaluation for the multifamily kits delivery channel.

Table 4. Kitchen Faucet Aerator Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
People	2.67	PY14 Energy Kit Participant Survey (to be updated)	2.07	PY14 Community Savers Program Data (to be updated)
Faucet Time	4.5	Secondary Source[1]	4.5	Secondary Source[1]
Days	365	Conversion Factor (day/yr)	365	Conversion Factor (day/yr)
ΔGPM	0.7	PY13 Program Data (to be updated)[2]	0.7	PY13 Program Data (to be updated)[2]
T_{FAUCET}	93	Illinois TRM[3]	93	Illinois TRM[3]
T_{IN}	61.3	Ameren Missouri 2012 TRM[4]	61.3	Ameren Missouri 2012 TRM[4]
CP	1	Specific Heat of Water (Btu/lb-°F)	1	Specific Heat of Water (Btu/lb-°F)
Den	8.33	Density (lb/gal)	8.33	Density (lb/gal)
3,413	3,413	Conversion Factor (Btu/kWh)	3,413	Conversion Factor (Btu/kWh)
RE	0.98	Secondary Source[5]	0.98	Secondary Source[5]

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
Number of Faucets	3.04	Secondary Source[6] (to be updated)	2.4	PY13 Program Data (to be updated)

[1] Cadmus and Opinion Dynamics Evaluation Team 2013. pp. 10.

[2] The rated gallons per minute for the new faucet aerator will come from the PY16 program data and the rated gallons per minute for the base faucet aerator will be 2.2 gallons per minute, which is the federal rated maximum flow rate for faucets (10CFR430.32 (p) (DOE 1998).

[3] *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0.* pp. 178. 2016. Available online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf

[4] *Ameren Missouri 2012 Technical Resource Manual.* Appendix A. pp. 43. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483

[5] NREL 2009. pp. 12.

[6] This assumes one kitchen faucet per household, plus an average of 2.04 bathrooms per home, as determined in the Ameren Missouri 2012 potential study.

Bathroom Faucet Aerators

Cadmus plans to evaluate kitchen faucet aerators and bathroom faucet aerators separately each year from PY16 through PY18. We estimated per-unit savings for bathroom faucet aerators using the following algorithm:

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = \frac{People \times Faucet\ Time \times Days \times \Delta GPM \times (T_{FAUCET} - T_{IN}) \times C_P \times Den}{3{,}413 \times RE \times Number\ of\ Faucets}$$

Where:

People	=	The number of people using faucet aerators (people/household)
Faucet Time	=	The average length of faucet use per day (minutes/day)
Days	=	The number of days per year (day/yr)
ΔGPM	=	The difference in rated gallons per minute between the base unit and the new unit (gal/min)
ΔT	=	The temperature at the tap minus the temperature at the water main
T_{FAUCET}	=	The average water temperature out of the faucet (°F)
T_{IN}	=	The average inlet water temperature (°F)
C_P	=	The specific heat of water (Btu/lb-°F)
Den	=	The water density (lb/gal)
3,413	=	The conversion rate from Btu to kWh (Btu/kWh)

RE = The water heater's recovery efficiency

Number of faucets = The number of used faucets per home

Table 5 shows the inputs for the engineering algorithm used to determine savings from bathroom faucet aerators delivered through both the school kits and multifamily kits delivery channels. The inputs for number of people per home and number of faucets per home differ between the two delivery channels. Cadmus will update these values based on PY16 survey data. Until we have these data, for the purposes of this memo, we used the single-family value from the previous evaluation as a placeholder value for the school kits delivery channel, and used the multifamily value from the previous evaluation for the multifamily kits delivery channel.

Table 5. Bathroom Faucet Aerator Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
People	2.67	PY14 Energy Kit Participant Survey (to be updated)	2.07	PY14 Community Savers Program Data (to be updated)
Faucet Time	1.6	Secondary Source[1]	1.6	Secondary Source[1]
Days	365	Conversion Factor (day/yr)	365	Conversion Factor (day/yr)
ΔGPM	0.7	PY13 Program Data (to be updated)[2]	0.7	PY13 Program Data (to be updated)[2]
T_{FAUCET}	86	Illinois TRM[3]	86	Illinois TRM[3]
T_{IN}	61.3	Ameren Missouri 2012 TRM[4]	61.3	Ameren Missouri 2012 TRM[4]
CP	1	Specific Heat of Water (Btu/lb-oF)	1	Specific Heat of Water (Btu/lb-oF)
Den	8.33	Density (lb/gal)	8.33	Density (lb/gal)
3,413	3,413	Conversion Factor (Btu/kWh)	3,413	Conversion Factor (Btu/kWh)
RE	0.98	Secondary Source[5]	0.98	Secondary Source[5]
Number of Faucets	3.04	Secondary Source[6] (to be updated)	2.4	PY13 Program Data (to be updated)

[1] Cadmus and Opinion Dynamics Evaluation Team. *Showerhead and Faucet Aerator Meter Study*. Memorandum prepared for Michigan Evaluation Working Group. 2013. pp. 10.

[2] The rated gallons per minute for the new faucet aerator will come from the PY16 program data and the rated gallons per minute for the base faucet aerator will be 2.2 gallons per minute, which is the federal rated maximum flow rate for faucets (DOE 1998).

[3] *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0.* pp. 178. 2016. Available online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf

[4] *Ameren Missouri 2012 Technical Resource Manual.* Appendix A. pp. 43. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483

[5] NREL 2009. pp. 12.

[6] Assumes one kitchen faucet per household, plus an average of 2.04 bathrooms per home, as determined by the Ameren Missouri 2012 potential study.

LEDs

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

$$Energy\ Savings\ (kWh/Year) = \frac{(Watt_{Base} - Watt_{EE}) \times Hours_{RES} \times Days}{1{,}000} \times WHF$$

Where:

$Watt_{Base}$	=	Wattage of the original incandescent bulb replaced by LED
WattEE	=	Wattage of new LED installed
$Hours_{RES}$	=	The average hours of use per day
Days	=	Days used per year
1,000	=	The conversion factor from Wh to kWh
WHF	=	Waste heat factor (to account for interactive effects)

Table 6 provides assumptions for LED savings. Cadmus will use the same engineering algorithm for school and multifamily kits, but will adjust the waste heat factor value based on the kit type.

Table 6. LED Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
$Watts_{Base}$	43	The lumen-equivalent halogen wattage for LEDs	43	The lumen-equivalent halogen wattage for LEDs
$Watts_{EE}$	9	9-watt ENERGY STAR LEDs with 800 lumen output.	9	9-watt ENERGY STAR LEDs with 800 lumen output
$Hours_{RES}$	3.1	2014 light metering study, adjusted for room-level saturation from the PY10 home inventory	3.1	2014 light metering study, adjusted for room-level saturation from the PY10 home inventory
Days	365	Conversion Factor (day/yr)	365	Conversion Factor (day/yr)
1,000	1,000	Conversion Factor (Wh/kWh)	1,000	Conversion Factor (Wh/kWh)
WHF	0.98	PY13 Engineering Simulation Modeling adjusted for heating and cooling saturations (to be updated)	0.98	PY13 Engineering Simulation Modeling adjusted for heating and cooling saturations (to be updated)

Water Heater Pipe Wrap

Cadmus estimated per-unit savings from pipe wrap using the following algorithm:

$$Energy\ Savings\ (kWh/Year) = \frac{\left(\left(\frac{1}{R_{EXIST}} - \frac{1}{R_{NEW}}\right) \times L \times C \times \Delta T \times 8{,}760\right)}{RE \times 3413}$$

Where:

R_{EXIST} = Pipe heat loss coefficient of uninsulated pipe (existing; Btu/hr-°F-ft; = 1.0)

R_{NEW} = Pipe heat loss coefficient of insulated pipe (new; Btu/hr-°F-ft)

L = Length of pipe from a water heating source covered by pipe wrap (in feet)

C = Circumference of pipe (in feet; = diameter (in) * π * 0.083)

ΔT = Average temperature difference between supplied hot water and ambient air temperatures (°F)

8,760 = The number of hours per year during which heat loss occurs (hr/yr)

RE = Recovery efficiency of the electric hot water heater

3,413 = The conversion rate from Btu to kWh (Btu/kWh)

Table 7 shows the inputs for the engineering algorithm used to determine savings for pipe wrap delivered through both the school kits and multifamily kits delivery channels. The inputs for length of pipe from a water heating source covered by pipe wrap and average temperature difference between supplied hot water and ambient air temperatures differ between the two delivery channels. Cadmus will update these values based on PY16 survey data. Until we have these data, for the purposes of this memo, we used the single-family value from the previous evaluation as a placeholder value for the school kits delivery channel, and used the multifamily value from the previous evaluation for the multifamily kits delivery channel

Table 7. Pipe Wrap Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
R_{EXIST}	1	Secondary Source[1]	1	Secondary Source[1]
R_{NEW}	4	PY14 Program Data (to be updated)	4	PY14 Program Data (to be updated)
L	3	PY16 assumption (to be updated)	3	PY16 assumption (to be updated)
C	0.196	Calculated (assumed 3/4-inch diameter)[2]	0.196	Calculated (assumed 3/4-inch diameter)[2]
ΔT	67.5 – single-family	Secondary Source; Ameren Missouri 2012 TRM[3]	58.9 – multifamily	Secondary Source; PY11MFIQ site-visits[4]
8,760	8,760	Constant (Hours per year)	8,760	Constant (Hours per year)
RE	0.98	Secondary Source[5]	0.98	Secondary Source[5]
3,413	3,413	Conversion Factor (Btu/kWh)	3,413	Conversion Factor (Btu/kWh)

[1] Navigant Consulting Inc. "Measures and Assumptions for Demand Side Management Planning; Appendix C Substantiation Sheets." pp. 77. April 2009.

[2] This 3/4-inch is standard pipe diameter.

[3] Ambient air temperature is 67.5°F based on: U.S. Department of Energy. *Test Procedure for Water Heaters.* May 11, 1998. Available online: http://www.gpo.gov/fdsys/pkg/FR-1998-05-11/pdf/98-12296.pdf.
The hot water temperature is 135°F according to Ameren Missouri 2012 TRM.

[4] Ambient air temperature is 67.5°F based on DOE 1998. Hot water temperature of 126.4°F based on site visits.

[5] NREL 2009. pp. 12.

Furnace Filter Alarms

Cadmus estimated furnace filter alarm savings using the following algorithm for alarms delivered through both the school kits and multifamily kits delivery channels:

$$\Delta\text{kWh/yr} = \left(\frac{\Delta\text{kWh}}{yr_{heat}} + \frac{\Delta\text{kWh}}{yr_{cool}}\right)$$

$$\frac{\Delta\text{kWh}}{yr_{heat}} = kW_{motor} \text{ x } EFLH_{heat} \text{ x EI}$$

$$\frac{\Delta\text{kWh}}{yr_{cool}} = kW_{motor} \text{ x } EFLH_{cool} \text{ x EI}$$

Where:

kW_{motor} = Average motor full load electric demand (kW)

$\text{EFLH}_{\text{heat}}$ = Estimated full-load heating hours for region (hours/year)

$\text{EFLH}_{\text{cool}}$ = Estimated full-load cooling hours for region (hours/year)

EI = Efficiency improvement (%)

Table 8 shows the input values used in the furnace filter alarm algorithm and their sources.

Table 8.Furnace Filter Alarm Savings Assumptions

Term	Value: School	Source: School	Value: Multifamily	Source: Multifamily
kW_{motor}	0.5	Pennsylvania TRM[1]	0.5	Pennsylvania TRM[1]
$\text{EFLH}_{\text{heat}}$	2,009	Ameren Missouri 2012 TRM[2] (to be updated)	2,009	Ameren Missouri 2012 TRM[2] (to be updated)
$\text{EFLH}_{\text{cool}}$	602	PY15 Metering Results [2] (to be updated)	602	PY15 Metering Results (to be updated)
EI	15%	Pennsylvania TRM[1]	15%	Pennsylvania TRM[1]

[1] Public Utilities Commission. *State of Pennsylvania Technical Reference Manual.* pp 73. 2016. Available online: http://www.puc.pa.gov/pcdocs/1370278.docx

[2] *Ameren Missouri 2012 Technical Resource Manual.* Appendix A. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483