



MEMORANDUM

To: Laureen Welikson and Greg Lovett; Ameren Missouri
 From: Laura James, Sara Wist, and Jane Colby; Cadmus
 Subject: PY16 Review of Lighting Estimates in Ameren Missouri TRM
 Date: December 2, 2016

This memo outlines the methodology and results of Cadmus’ review of the 2016 Ameren Missouri Technical Reference Manual (TRM) and deemed per-unit savings for measures offered through the Ameren Missouri Lighting Program for program year 2016 (PY16) through PY18. Through the program, Ameren Missouri offers discounts on nine measure categories of LED bulbs, listed in Table 1.

Ameren Missouri established these category names in its PY16-PY18 filing,¹ but did not define each category. Cadmus proposes the category definitions shown in Table 1, including the bulb type and specification guidelines, to more precisely identify which program bulbs we will assign to each category for the PY16 evaluation. The definitions are broader than the name itself; for example, the proposed definition for the category name “12W_LED_Dimmable” does not require bulbs that are 12 watts or dimmable. Instead, the bulbs in this category are similar in design to a general purpose bulb, but are exempt from EISA regulations due to a special feature (such as three-way lumen output or shatter-resistant exterior).

Several measure categories included in the PY16 Lighting Program are new to the 2016 Ameren Missouri TRM (from the 2012 TRM), including the 10W_LED, 15W_LED, 20W_LED, and 4W_LED_Candelabra measure categories. The remaining five measure categories existed in the 2012 TRM, but Cadmus has proposed a new definition for the category.

Table 1. Lighting Program Measure Categories, PY16 Through PY18

Measure Category	Bulb Type	Specification Guidelines
10W_LED	General purpose	60-watt equivalent or less, determined by lumen output
15W_LED	General purpose	75-watt equivalent, determined by lumen output
20W_LED	General purpose	100-watt equivalent, determined by lumen output
4W_LED_Candelabra	Decorative	Small- and medium-base candle-shaped bulbs, all wattages
8W_LED_Globe_Light	Decorative	Small- and medium-base globe-shaped bulbs, all wattages
12W_LED_Dimmable	EISA exempt	Bulbs that otherwise would be subject to EISA as general

¹ Ameren Missouri 2016-2018 Energy Efficiency Plan. Missouri Public Service Commission file number EO-2015-0055, Appendix G. Available online: https://projects.cadmusgroup.com/sites/6320-P02/phase01/Shared%20Documents/Management/PY16%20Proposed%20Stipulated%20and%20Agreement%20Files/Appendix%20G%20-%20Measure_List_Incentives%20Range_Design.pdf?Web=1

		purpose bulbs, but are exempt due to special features (e.g., three-way)
10.5W_LED_Downlight	Reflector	Bulb diameter of 20 eighths of an inch or less (2.5 inches or less)
15W_LED_Flood_Light_PAR30	Reflector	Bulb diameter more than 20 eighths of an inch, at 1,789 lumens or below
18W_LED_Flood_Light_PAR38	Reflector	Bulb diameter more than 20 eighths of an inch, above 1,789 lumens

Summary Results

Cadmus compared the per-unit energy savings estimated in the 2016 TRM with energy savings we calculated based on the PY15 evaluation and preliminary analysis for PY16. Table 2 lists the TRM-based per-unit savings and Cadmus-estimated per-unit gross savings by measure. The evaluated per-unit gross savings for PY16 will reflect program activity throughout the year, as well as updated values for leakage, the percentage of bulbs installed in residential applications, and the waste heat factor for residential bulbs. As a result, evaluated per-unit gross savings may differ from the values presented in this memo.

Table 2. 2016 TRM and Estimated Per-Unit Savings Summary

Bulb Type	Measure Category	Per-Unit Energy Savings (kWh/yr)		Percentage Difference
		TRM	Cadmus Estimated*	
General Purpose	10W_LED	28.0	38.2	36%
	15W_LED	33.5	50.0	49%
	20W_LED	51.0	66.5	30%
Decorative	4W_LED_Candelabra	26.4	42.0	59%
	8W_LED_Globe_Light	33.5	42.8	28%
EISA Exempt	12W_LED_Dimmable	28.0	77.7	178%
Reflector	10.5W_LED_Downlight	26.8	40.8	52%
	15W_LED_Flood_Light_PAR30	33.5	60.1	79%
	18W_LED_Flood_Light_PAR38	33.5	88.2	163%

* These estimated values are based on assumptions from the PY15 evaluation, preliminary results for 2016, or on other sources, in cases where the input values for the PY16 evaluation were not available. The source of each input value used for these estimates is presented in Table 3.

TRM Per-Unit Savings Methodology

Cadmus reviewed the 2016 TRM deemed per-unit savings for all program measure categories. However, the 2016 TRM does not provide the algorithm or inputs used to determine those deemed values, and therefore we could not directly compare the basis for the deemed values with the inputs values we used in our analysis.

Estimated Per-Unit Savings Methodology

Cadmus estimated per-unit savings using the industry standard algorithm, along with inputs derived through protocols recommended in the Uniform Methods Project.² We calculated the savings value for each measure category as the sum of the following two equations:

$$\Delta kWh_{RES} = \frac{(Watt_{Base} - Watt_{EE}) * \%RES * ISR * (1 - LKG) * (Hours_{RES} * Days * WHF_{RES})}{1,000}$$

$$= \frac{\Delta kWh_{NRES}}{(Watt_{Base} - Watt_{EE}) * (1 - \%RES) * ISR * (1 - LKG) * (Hours_{NRES} * Days * WHF_{NRES})} * 1,000$$

Where:

Watt _{Base}	=	Wattage of the baseline alternative bulb displaced by program bulb
Watt _{EE}	=	Wattage of program bulb
%Res	=	Percentage of program bulbs installed in residential applications as opposed to nonresidential applications
ISR	=	In-service rate
LKG	=	Leakage rate (program bulbs sold to customers outside Ameren Missouri's service area)
Hours _{RES}	=	Average hours-of-use (HOU) per day for bulbs installed in residential applications
Hours _{NRES}	=	Average HOU per day for bulbs installed in nonresidential applications
Days	=	Days used per year
WHF _{RES}	=	HVAC interaction factor (adjustments for HVAC interactive effects) for bulbs installed in residential applications
WHF _{NRES}	=	HVAC interaction factor (adjustments for HVAC interactive effects) for bulbs installed in nonresidential applications
1,000	=	Conversion factor from Wh to kWh

Table 3 shows the source for each input value required for the PY16 evaluation, as well as details of how Cadmus will calculate each value for the PY16 evaluation. The table also the source of the input value we used for the estimates presented in Table 2.

² Dimetrosky, S., K. Parkinson, N. Lieb. *Uniform Methods Project, Chapter 21: Residential Lighting Evaluation Protocol*. National Renewable Energy Laboratory. February 2015. Available online: <http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf>

Table 3. Source for PY16 LED Input Values

Data Required	Data Source for PY16 Evaluation	Data Source for Estimates Shown in Table 2
Watts _{Base}	Sales-weighted average of the baseline for each model in the measure category, using complete PY16 sales data. Baseline wattage is determined by the lumen-per-watt output using the ENERGY STAR® reference database, or the manufacturer’s stated equivalent baseline, as appropriate for each measure category.	Estimated baseline for the average lumen per bulb for each measure category, sold through September 2016.
Watts _{EE}	Sales-weighted average of the wattages of program bulbs in each measure category, using complete PY16 sales data.	Sales-weighted average of the wattages of program bulbs in each measure category, sold through September 2016.
%RES	PY16 store intercept study: survey of 600 shoppers in 30 participating retailer locations.	Estimated based on preliminary results from 2016 store intercept surveys.
ISR	PY15 home inventory study from a sample of 100 homes that compares stored bulbs to installed bulbs.	Same as source for PY16 evaluation.
LKG	PY16 store intercept study: survey of 600 shoppers in 30 participating retailer locations.	PY13 store-intercept survey, adjusted based on PY15 sales distribution.
Hours _{RES}	PY10 HOU study, adjusted based on 2015 home inventory study: analysis of light meters installed in inventory homes in PY10, adjusted to reflect distribution of LEDs by room in PY15 home inventory.	Same as source for PY16 evaluation.
Hours _{NRES}	Average value for indoor nonresidential spaces from the California Database for Energy Efficient Resources 2008. ³	Same as source for PY16 evaluation.
WHF _{RES}	Cadmus modeling analysis, PY13.	Same as source for PY16 evaluation.
WHF _{NRES}	Cadmus modeling analysis, PY13.	Same as source for PY16 evaluation.

Input Value Comparisons

As Table 2 shows, the evaluated per-unit savings are higher than the TRM deemed savings for all measure categories. Several factors may contribute to these differences. While the exact algorithm used to calculate the TRM values is not known, the electronic database that Ameren Missouri used to prepare the TRM (the Online iEnergy Technical Reference Library [iTRL]) includes some input values for each measure category, which we assumed were incorporated into the savings algorithm. These values for each measure are presented in Table 4.

³ Summit Blue Consulting. California Database for Energy Efficient Resources. 2008. Available online: <http://www.deeresources.com/index.php/23-deer-versions>

Table 4. iTRL Input Values for Deemed Savings by Measure Category

Measure Category	Watt _{Base}	Watt _{Ee}	ISR	%Res
10W_LED	47.0	10.0	96%	100% Residential
15W_LED	53.0	15.0	96%	100% Residential
20W_LED	72.0	20.0	96%	100% Residential
4W_LED_Candelabra	40.0	4.0	96%	100% Residential
8W_LED_Globe_Light	72.0	8.0	96%	100% Residential
12W_LED_Dimmable	43.0	12.0	96%	100% Residential
10.5W_LED_Downlight	47.0	10.5	96%	100% Residential
15W_LED_Flood_Light_PAR30	50.0	15.0	96%	100% Residential
18W_LED_Flood_Light_PAR38	50.0	18.0	96%	100% Residential

For measure categories included in the program in previous years, the iTRL cites previous Ameren Missouri evaluation materials (typically the PY13 Dashboard workbook for the Lighting Program) as the basis for the input values. The iTRL does not cite resources for new measures, including the 10W_LED, 15W_LED, 20W_LED, and 4W_LED_Candelabra.

Baseline Wattage

The baseline bulb is the most likely alternative bulb, and is being displaced by the program bulb. Federal policy prohibiting the manufacture of certain general purpose and decorative bulbs above a certain wattage has provided a *de facto* baseline for those bulbs, equivalent to halogen technology.

Federal policy also limits the maximum wattage for some reflector bulbs, using a formula that accounts for bulb size and lumen output. The baseline for reflector bulbs is therefore more variable, and is not directly tied to a particular technology. ENERGY STAR maintains a database of common models of reflector bulbs and the maximum allowed baseline wattage given the bulb’s specification. Where available, Cadmus used this value as the baseline wattage for program reflector bulbs. For bulb models not represented in the database, Cadmus used the manufacturer’s stated wattage-equivalent. We applied the sales-weighted baseline average of the bulbs in each measure category as the baseline wattage for that category.

Cadmus estimated baseline wattages based on an assumed mix of program bulbs in each category for PY16. Table 6 lists estimated, preliminary efficient and baseline wattages by measure category. We will update these values for the PY16 evaluation based on the year-end program sales data.

Table 5. iTRL and Cadmus Estimates for Watt_{Base} for PY16

Measure Name	iTRL Value	Cadmus Estimated Value
10W_LED	47.0	41.3
15W_LED	53.0	53.0
20W_LED	72.0	72.0
4W_LED_Candelabra	40.0	39.7
8W_LED_Globe_Light	72.0	41.9
12W_LED_Dimmable	43.0	73.5
10.5W_LED_Downlight	47.0	42.2
15W_LED_Flood_Light_PAR30	50.0	62.0
18W_LED_Flood_Light_PAR38	50.0	90.0

Cadmus’ estimates of the baseline wattage for the 10W_LED, 4W_LED_Candelabra, 8W_LED_Globe_Light, and 10.5W_LED_Downlight are lower than the iTRL assumed values. This difference is most likely the result of a slightly different bulb mix in the category than the iTRL anticipated. In the case of the globe light category, the baseline for bulbs can range from 40 watts to 72 watts. The majority of bulbs sold in this category to date have between 350 and 499 lumens, which indicates a baseline of 40 watts.

The Cadmus-estimated baseline for the 12W_LED_Dimmable category of 61.9 watts is significantly higher than the iTRL assumed baseline of 43 watts. Cadmus does not know the basis for the iTRL assumed value, but notes that 43 watts is the appropriate baseline for general purpose bulbs equivalent to 60-watt incandescent bulbs. However, according to Cadmus’ proposed definition, this measure category includes only A-line omnidirectional bulbs that have a special feature designation (and therefore are not considered general purpose), to avoid overlap with the 10W_LED measure category. Bulbs with a special feature, such as three-way lighting, are not subject to federal rules restricting maximum wattage. Therefore, Cadmus applied the wattage of lumen-equivalent incandescent bulbs as the baseline for this measure category. The majority of bulbs sold to date in this category have a baseline of 60 watts, and a small number have a baseline of 75 watts.

Efficient Wattage

The per-unit savings depends in large part on the delta between the wattage of the program bulb (efficient wattage) and the wattage of the baseline bulb. For the PY16 evaluation, Cadmus will use the sales-weighted average of the wattage of program bulbs in that category as the measure category efficient wattage.

As shown in Table 5, for all measures except the 4W_LED_Candelabra, Cadmus’ estimate for efficient wattage is below the TRM assumed efficient wattage. This may be a result of the program bulb mix in each category including bulbs with a lower average wattage than the iTRL anticipated. Assuming the baseline wattage remains the same, a lower efficient wattage should increase the per-unit savings for each measure by increasing the delta between the baseline and efficient wattage relative to the TRM

assumption. Cadmus will update these values for the PY16 evaluation based on the year-end program sales data.

Table 6. iTRL and Cadmus Estimates of Watt_{EE} for PY16

Measure Name	iTRL Value	Cadmus Estimated Value
10W_LED	10.0	9.3
15W_LED	15.0	11.1
20W_LED	20.0	16.2
4W_LED_Candelabra	4.0	4.5
8W_LED_Globe_Light	8.0	6.0
12W_LED_Dimmable	12.0	8.3
10.5W_LED_Downlight	10.5	8.0
15W_LED_Flood_Light_PAR30	15.0	11.6
18W_LED_Flood_Light_PAR38	18.0	16.0

In-Service Rate

The TRM applies a 96% in-service rate (ISR) for all measure categories. Cadmus also uses a uniform ISR for all measures, calculated as the present value of likely bulb installations over a four year period, beginning with an initial-year installation rate determined through a home inventory study. For PY16, Cadmus applied the initial-year installation rate of 79.5%, based on the results of the home inventory study we conducted in PY15. The resulting present value of installation over four years is 94.8%. Cadmus will use this value for the final PY16 evaluation.

The evaluation ISR is slightly lower than the TRM assumed ISR, and therefore has a downward impact on per-unit savings relative to the TRM value.

Percent Residential

The 2016 TRM notes that the applicable sector is residential for all measure categories, and makes no mention of potential savings from bulbs installed in nonresidential applications. In contrast, in our evaluation methodology, Cadmus accounts for the percentage of bulbs being installed in nonresidential applications, which achieve significantly increased savings due primarily to longer hours of use. From PY13 to PY15, this value ranged from 9% to 16% (calculated as 1- %Res). Early results from the in-store surveys, ongoing at the time of this writing, indicate a lower amount of bulbs being installed in nonresidential applications than in previous years. Cadmus assumed 5% of PY16 bulbs will go to nonresidential applications value for the per-unit savings estimates shown in Table 2. We will update this value for the PY16 evaluation based on the final store-intercept survey results.

Summary of Evaluation Input Values

Table 7 lists all of the input values used for the estimated evaluated per unit savings presented in this memo.

Table 7. Summary of Preliminary Evaluation Input Values, PY2016

Input	Measure Category								
	10W_LED	15W_LED	20W_LED	4W_LED_Candelabra	8W_LED_Globe_Light	12W_LED_Dimmable	10.5W_LED_Downlight	15W_LED_Flood_Light_PAR30	18W_LED_Flood_Light_PAR38
WattsEE	9.3	11.1	16.2	4.5	6.0	8.3	8.0	11.6	16.0
WattsBase	41.3	53.0	72.0	39.7	41.9	73.5	42.2	62.0	90.0
	All Categories								
%Res	95.0%								
ISR	1.8%								
LKG	94.8%								
HoursRES	3.1								
Hours NRES	9.9								
WHFRES	0.99								
WHFNRES	1.10								