# MEMORANDUM

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| To: | Laureen Welikson and Greg Lovett; Ameren Missouri |
| From: | David Ladd, Brian Evans, Sara Wist, and Jane Colby; Cadmus |
| Subject: | PY16 Efficient Products Program: TRM Gross Savings |
| Date: | November 30, 2016 |

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

- Heat pump water heaters
- ENERGY STAR® room air conditioners
- ENERGY STAR room air cleaners
- ENERGY STAR dual speed pool pumps
- ENERGY STAR variable speed pool pumps
- Smart thermostats

## Measure-Specific Gross Savings Methodology

Cadmus estimated gross savings for most program measures using the engineering algorithms established in the Efficient Products Evaluation Plan.[1] We then compared the deemed per-unit savings as provided in Ameren Missouri's Technical Reference Manual (TRM)[2] to our own gross savings estimates. For the Smart Thermostat measure, Cadmus assessed the reasonableness of the deemed per-unit savings by comparing with Illinois' TRM values[3].

The calculations in this memo are per-unit savings estimates that do not include adjustments for installation rates 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.

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[1]   Cadmus. "Evaluation Plan: Residential Efficient Products Program (PY16-PY18)." September 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.

[3]   Available online: http://www.ilsag.info/il_trm_version_5.html

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## Estimated Savings Results

Cadmus reviewed best practices for calculating energy savings for program measures, and compared per-unit savings estimated in the 2016 Ameren Missouri Technical Reference Manual (TRM) with savings developed through up-to-date ENERGY STAR calculators. Table 1 lists TRM-based per-unit savings (*ex ante*) by measure.

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

| Measure | TRM Per-Unit Savings (kWh/yr) | Cadmus Estimated Per-Unit Savings (kWh/yr)* |
|---|---|---|
| Heat Pump Water Heaters | 3,315 | 2,865 |
| ENERGY STAR Room Air Conditioners | 49.6 | 49.6 |
| ENERGY STAR Room Air Cleaners | 482 | 515 |
| ENERGY STAR Dual Speed Pool Pumps | 1,799.7 | 1,799.7 |
| ENERGY STAR Variable Speed Pool Pumps | 1,543 | 2,053 |
| Smart Thermostats | 462 | 462 |
| * Cadmus estimates are presented with and without decimals maintain consistency with TRM per-unit values. | | |

Cadmus engineers reviewed the 2016 TRM deemed per-unit savings for all program measures. We then compared these assumptions to the latest ENERGY STAR calculators to develop estimated per unit savings numbers. The remainder of this memo outlines the estimated per-unit savings for each measure along with the algorithm and inputs used.

### Heat Pump Water Heaters

Cadmus estimated per-unit savings for heat pump water heaters using the following algorithm:

$$Energy\ Savings\ (kWh/Year)$$
$$= \left(\frac{1}{EFbase} - \frac{1}{EFeff}\right) \times (HWT - CWT) \times Den \times GPD \times 365 \times C_p \times \frac{1}{3,413}$$
$$- kWhheat + kWhcool$$

Where:

| | | |
|---|---|---|
| EFbase | = | Energy factor of baseline water heater |
| EFeff | = | Energy factor of program-qualified water heater |
| HWT | = | Hot water temperature ($^o$F) |
| CWT | = | Cold water temperature ($^o$F) |
| Den | = | The water density (lb/gal) |
| GPD | = | Gallons of hot water used per day |
| 365 | = | Days/year |
| $C_p$ | = | Specific heat of water |
| 3,413 | = | Conversion factor from Btu to kWh |

| | kWhheat | = | Heating interaction due to heat removed from room to heat water |
|---|---|---|---|

kWhheat     =     Heating interaction due to heat removed from room to heat water

kWhcool     =     Cooling interaction due to heat removed from room to heat water

Table 2 shows the assumed value of each of these parameters.

#### Table 2. Heat Pump Water Heaters Savings Assumptions

| Term | Value | Source |
|---|---|---|
| EFbase | 0.90 | Federal minimum standard |
| EFeff | 2.7 | PY16 Efficient Products Database (average EF)* |
| HWT | 135 | Ameren Missouri TRM |
| CWT | 61.3 | Ameren Missouri TRM |
| Den | 8.33 | Density of water (lb/gallon) |
| GPD | 64 | Secondary source** |
| $C_P$ | 1 | Specific heat of water (Btu/lb-oF) |
| 3,413 | 3,413 | Conversion factor (Btu/kWh) |
| kWhheat | Electric Resistance = 1,577<br>Heat Pump = 779 | Ohio Statewide TRM*** |
| kWhcool | 180 | Ohio Statewide TRM*** |
| Days | 365 | Conversion Factor (day/yr) |

\* Value updated from PY14.

\*\* DOE Federal Energy Management Program Energy Cost Calculator. Available online:
http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0

\*\*\* Cadmus adjusted interactive effects to account for the saturation of electric resistance heat, heat pumps, and central air conditioners in Ameren Missouri's territory, as found by the PY14 Efficient Products survey (11%, 29%, and 91%, respectively). *State of Ohio Energy Efficiency Technical Reference Manual.* pp. 86-87. 2010. Available Online: http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf

Using this engineering algorithm, we estimated an energy savings value of 2,865 kWh per year for each installed and retained heat pump hot water heater. This value was approximately 86% of the program *ex ante* value of 3,315 kWh per year (Table 3). The difference between these estimates is a result of adjustments Cadmus made to the saturation percentages of electric resistance heat, heat pumps, and central air conditioners (as mentioned in the footnote to Table 2).

#### Table 3. TRM and Estimated Savings Comparison for Heat Pump Water Heaters

| TRM Savings/Unit | Cadmus Estimated Savings/Unit | Realization Rate |
|---|---|---|
| 3,315 kWh/yr | 2,865 kWh/yr | 86% |

### ENERGY STAR Room Air Conditioners

Cadmus estimated per-unit savings for room air conditioners using the following algorithm:

$$Energy\ Savings\ (kWh/Year) = \frac{\frac{BTU}{hr} \times \left(\frac{1}{EER_{BASE}} - \frac{1}{EER_{EFF}}\right) \times EFLH_{COOL}}{1,000}$$

Where:

| | | |
|---|---|---|
| Btu/hr | = | Room air conditioner cooling capacity (Btu/hour) |
| $EER_{BASE}$ | = | Baseline equipment energy efficiency ratio (Btu/W-hour) |
| $EER_{EFF}$ | = | Efficient equipment energy efficiency ratio (Btu/W-hour) |
| $EFLH_{COOL}$ | = | Equivalent full-load cooling hours |
| 1,000 | = | Conversion from between Wh to kWh |

Table 4 shows the assumed value of each of these parameters.

### Table 4. Room Air Conditioner Savings Assumptions

| Term | Value | Source |
|---|---|---|
| Btu/hr | 9,558 | PY13 Efficient Products Program Database (average Btu/hr) |
| $EER_{BASE}$ | 9.8 | Federal minimum efficiency standard |
| $EER_{EFF}$ | 10.7 | PY13 Efficient Products Program Database (average EER) |
| $EFLH_{COOL}$ – primary unit* | 860 | PY13 CoolSavers Program data |
| $EFLH_{COOL}$ – secondary unit* | 556 | Secondary source** |
| 1,000 | 1,000 | Conversion factor (Wh/kWh) |

* Cadmus used a weighted average for $EFLH_{COOL}$ for primary and secondary sources, based on PY14 survey responses; 84% of respondents reported using their room air conditioner as a secondary cooling source.
** This value is based on weather-adjusted metering data from California: Cadmus. *Residential Retrofit High Impact Measure Evaluation Report: Evaluation of PGE2000, SDGE3024, & SCE2501 Room Air Conditioners (2006-2008)*. 2010. Available online: http://www2.epa.gov/sites/production/files/documents/CA_PUC_Assessment.pdf

Using this engineering algorithm, we estimated an energy savings value of 49.6 kWh per year for each installed and retained room air conditioner. This value is equivalent to the program's *ex ante* savings estimate (see Table 5).

### Table 5. TRM and Estimated Savings Comparison for Room Air Conditioners

| TRM Savings/Unit | Cadmus Estimated Savings/Unit | Realization Rate |
|---|---|---|
| 49.6 kWh/yr | 49.6 kWh/yr | 100% |

## ENERGY STAR Room Air Cleaners

Cadmus estimated per-unit ENERGY STAR room air cleaner savings using the following ENERGY STAR calculator algorithm:

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = \left\{ \left(\frac{1}{Eff_{BL}}\right) - \left(\frac{1}{Eff_{ES}}\right) \times \left(Hr_{oper}\right) + (SB_{BL} - SB_{ES}) \times \left(24 - Hr_{oper}\right)\right\} \times \frac{365}{1,000}$$

Where:

| | | |
|---|---|---|
| $Eff_{BL}$ | = | Clean air recovery rate for dust per watt for baseline unit |
| $Eff_{ES}$ | = | Clean air recovery rate for dust per watt for ENERGY STAR unit |

$$Hr_{oper} \quad = \quad \text{Hours per day of operation}$$

$$SB_{BL} \quad = \quad \text{Standby for baseline unit}$$

$$SB_{ES} \quad = \quad \text{Standby for ENERGY STAR unit}$$

$$365 \quad = \quad \text{Days/year}$$

$$1{,}000 \quad = \quad \text{Conversion factor (Wh/kWh)}$$

Table 6 shows the assumed value of each of these parameters.

**Table 6. ENERGY STAR Room Air Cleaner Savings Assumptions**

| Term | Value | Source |
|---|---|---|
| $Eff_{BL}$ | 1.00 | ENERGY STAR Appliance Calculator* |
| $Eff_{ES}$ | 2.77 | PY15 Efficient Products Program Database |
| $Hr_{oper}$ | 16 | ENERGY STAR Appliance Calculator* |
| $SB_{BL}$ | 1.00 | ENERGY STAR Appliance Calculator * |
| $SB_{ES}$ | 0.272 | PY15 Efficient Products Program Database |
| Clean air recovery rate for dust | 137.59 | PY15 Efficient Products Program Database |

*Available online:
https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Using this engineering algorithm, we estimated a per-unit savings value of 515 kWh per year for each ENERGY STAR room air Cleaner (shown in Table 7). This value was approximately 107% of the program's *ex-ante* savings estimate (482 kWh per year).The difference between estimates resulted from updates to the clean-air delivery rate for dust and the standby energy consumption based on PY16 program data.

**Table 7. TRM and Estimated Savings Comparison for ENERGY STAR Room Air Cleaners**

| TRM Savings/Unit | Cadmus Estimated Savings/Unit | Realization Rate |
|---|---|---|
| 482 kWh/yr | 515 kWh/yr | 107% |

## ENERGY STAR Dual Speed Pool Pumps

Cadmus estimated per-unit dual speed pool pump savings using the following algorithm:

$$Energy\ Savings\left(\frac{kWh}{Year}\right) = Days_{oper} \times \left\{\left(\frac{kWh_{ss}}{Day}\right) - \left(\frac{kWh_{ds}}{Day}\right)\right\}$$

Where:

$$\left(\frac{kWh_{ss}}{Day}\right) = \frac{(RT_{ss} \times GPM_{ss} \times 60)}{(EF_{ss} \times 1{,}000)}$$

$$\left(\frac{kWh_{ds}}{Day}\right) = \left(\frac{kWh_{hs}}{Day}\right) + \left(\frac{kWh_{ls}}{Day}\right)$$

$$\left(\frac{kWh_{hs}}{Day}\right) = \frac{(RT_{hs} \times GPM_{hs} \times 60)}{(EF_{hs} \times 1{,}000)}$$

$$\left(\frac{kWh_{ls}}{Day}\right) = \frac{(RT_{ls} \times GPM_{ls} \times 60)}{(EF_{ls} \times 1{,}000)}$$

And where:

| | | |
|---|---|---|
| $Days_{oper}$ | = | Days/year of operation |
| $RT_{ss}$ | = | Runtime in hours/day using single-speed pump |
| $GPM_{ss}$ | = | Gallons per minute using single-speed pump |
| $EF_{ss}$ | = | Energy factor using single-speed pump |
| $RT_{hs}$ | = | Runtime in hours/day in high speed using dual-speed pump |
| $GPM_{hs}$ | = | Gallons per minute in high speed using dual-speed pump |
| $EF_{hs}$ | = | Energy factor in high speed using dual-speed pump |
| $RT_{ls}$ | = | Runtime in hours/day in low speed using dual-speed pump |
| $GPM_{ls}$ | = | Gallons per minute in low speed using dual-speed pump |
| $EF_{ls}$ | = | Energy factor in low speed using dual-speed pump |
| 1,000 | = | Conversion factor (Wh/kWh) |

Table 8 shows the assumed value of each of these parameters.

**Table 8. ENERGY STAR Dual Speed Pool Pump Savings Assumptions**

| Term | Value | Source |
|---|---|---|
| $Days_{oper}$ | 121.6 | |
| $RT_{ss}$ | 11.4 | |
| $RT_{ls}$ | 9.8 | |
| $RT_{hs}$ | 2.0 | |
| $GPM_{ss}$ | 64.4 | *ENERGY STAR Pool Pump Calculator adjusted for |
| $GPM_{ls}$ | 31.0 | dual speed in Missouri |
| $GPM_{hs}$ | 56.0 | |
| $EF_{ss}$ | 2.1 | |
| $EF_{ls}$ | 5.4 | |
| $EF_{hs}$ | 2.4 | |

*Available online:
https://www.energystar.gov/sites/default/files/asset/document/Pool%20Pump%20Calculator.xlsx

Using this engineering algorithm, we estimated a per-unit saving value of 1,799.7 kWh per year for dual-speed pool pumps (shown in Table 9). This value is equivalent to the program's *ex ante* savings estimate.

**Table 9. TRM and Estimated Savings Comparison for ENERGY STAR Dual Speed Pool Pumps**

| TRM Savings/Unit | Cadmus Estimated Savings/Unit | Realization Rate |
|---|---|---|
| 1,799.7 kWh/yr | 1,799.7 kWh/yr | 100% |

## ENERGY STAR Variable Speed Pool Pumps

Cadmus estimated per-unit variable speed pool pump savings using the following algorithm:

$$Energy\ Savings\ \left(\frac{kWh}{Year}\right) = Days_{oper} \times \left\{ \left(\frac{kWh_{ss}}{Day}\right) - \left(\frac{kWh_{vs}}{Day}\right) \right\}$$

Where:

$$\left(\frac{kWh_{ss}}{Day}\right) = \frac{(RT_{ss} \times GPM_{ss} \times 60)}{(EF_{ss} \times 1,000)}$$

$$\left(\frac{kWh_{vs}}{Day}\right) = \left(\frac{kWh_{hs}}{Day}\right) + \left(\frac{kWh_{ls}}{Day}\right)$$

$$\left(\frac{kWh_{hs}}{Day}\right) = \frac{(RT_{hs} \times GPM_{hs} \times 60)}{(EF_{hs} \times 1,000)}$$

$$\left(\frac{kWh_{ls}}{Day}\right) = \frac{(RT_{ls} \times GPM_{ls} \times 60)}{(EF_{ls} \times 1,000)}$$

And where:

| | | |
|---|---|---|
| $Days_{oper}$ | = | Days/year of operation |
| $RT_{ss}$ | = | Runtime in hours/day using single-speed pump |
| $GPM_{ss}$ | = | Gallons per minute using single-speed pump |
| $EF_{ss}$ | = | Energy factor using single-speed pump |
| $RT_{hs}$ | = | Runtime in hours/day in high speed using variable-speed pump |
| $GPM_{hs}$ | = | Gallons per minute in high speed using variable-speed pump |
| $EF_{hs}$ | = | Energy factor in high speed using variable-speed pump |
| $RT_{ls}$ | = | Runtime in hours/day in low speed using variable-speed pump |
| $GPM_{ls}$ | = | Gallons per minute in low speed using variable-speed pump |
| $EF_{ls}$ | = | Energy factor in low speed using variable-speed pump |
| 1,000 | = | Conversion factor (Wh/kWh) |

Table 10 shows the assumed value of each of these parameters.

**Table 10. ENERGY STAR Variable Speed Pool Pump Savings Assumptions**

| Term | Value | Source |
|---|---|---|
| $Days_{oper}$ | 121.6 | |
| $RT_{ss}$ | 11.4 | |
| $GPM_{ss}$ | 64.4 | |
| $EF_{ss}$ | 2.1 | *ENERGY STAR Pool Pump Calculator (version last updated December 2013) adjusted for variable speed in Missouri |
| $RT_{hs}$ | 2.0 | |
| $GPM_{ls}$ | 30.6 | |
| $EF_{ls}$ | 7.3 | |
| $RT_{ls}$ | 10.0 | |
| $GPM_{hs}$ | 50.0 | |
| $EF_{hs}$ | 3.8 | |

*Available online:
https://www.energystar.gov/sites/default/files/asset/document/Pool%20Pump%20Calculator.xlsx

Using this engineering algorithm, we estimated a per-unit saving value of 2,053 kWh per year for variable speed pool pumps (shown in Table 11). This value was approximately 133% of the program's *ex ante* per-unit savings of 1,543 kWh per year, based on motor efficiency, load factor, and horsepower and not using the ENERGY STAR calculator to estimate savings.

**Table 11. TRM and Estimated Savings Comparison for ENERGY STAR Variable Speed Poop Pumps**

| TRM Savings/Unit | Cadmus Estimated Savings/Unit | Realization Rate |
|---|---|---|
| 1,543 kWh/yr | 2,053 kWh/yr | 133% |

## Smart Thermostats

Cadmus reviewed the reasonableness of the *ex ante* unit savings estimate by comparing with the Illinois TRM. The Illinois TRM assumes savings of 7.4% of heating consumption and 8% of cooling consumption when replacing a thermostat of unknown type. Applying these savings percentages to heating and cooling consumption values from the Ameren Missouri billing analysis of ASHP participants and weighing by the heating system distribution for single-family homes taken from the ongoing PY16 Efficient Products participant surveys, produced an estimated per-unit savings of 470 kWh. This value is approximately 102% of the program's *ex ante* per-unit savings of 462 kWh per year and thus we consider the *ex ante* estimate to be reasonable and consistent with deemed values from other jurisdictions.