To: Ameren Missouri and parties participating in the Ameren Technical Conference for File No. EO-2012-0142

From: Adam Bickford, Missouri Department of Natural Resources, Division of Energy

Subject: MDNR/GDS Review of Ameren Missouri Technical Resource Manual

March 23, 2012

Ameren Missouri submitted a technical resource manual (TRM) documenting the measures and deemed savings values it planned to use to estimate savings from its DSM plan submitted in its January 20, 2012 MEEIA application (EO-2012-0142). MDNR has endorsed the use of a TRM in program planning and has been an advocate for the development of a statewide TRM throughout the MEEIA rule making process. We commend Ameren Missouri for compiling this TRM. We see Ameren's next three DSM program years, the years covered by Ameren's current MEEIA application, as an opportune time to test the use of a TRM in program operation and program evaluation.

MDNR recognizes the value of having accurate and consistent estimates of measure level savings as utilities work to meet the MEEIA policy goal of achieving all cost-effective demand-side savings. In that spirit, MDNR contracted with GDS Associates to review the equations and deemed savings estimates in Ameren's TRM to assist in our review of Ameren's MEEIA application. We determined that providing advance access to the results of GDS' review to participants in Ameren's MEEIA technical conferences was appropriate to provide insights into this independent review of the equations used in Ameren's TRM and to permit open and early discussion of the analysis and recommendations for select revisions of this important document.

MDNR recognizes that Ameren's TRM is the first step toward the development of a valuable energy efficiency resource. We look forward to working with Ameren and other parties to consider appropriate refinements to this innovative tool.

GDS Associates, Inc.
Engineers and Consultants

FINAL REPORT

Missouri Department of Natural Resources

Review of Energy Savings Equations in Ameren Missouri's Technical Resource Manual

Ameren Missouri's Filing to Implement Regulatory Changes in Furtherance of Energy Efficiency as allowed by MEEIA.2012 Energy Efficiency Filing

(File No. EO-2012-0142)

March 19, 2012

GDS Associates, Inc.
1850 Parkway Place
Suite 800
Marietta, GA 30067
770.425.8100
770.426.0303 (Fax)
www.gdsassociates.com

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1.0 INTRODUCTION

The Missouri Department of Natural Resource (MDNR) contracted with GDS Associates (GDS) to conduct an engineering and technical review of energy savings equations and estimated annual energy savings values presented in Ameren Missouri's Technical Resource Manual (TRM)[1] as filed in Case No. EO-2012-0142. This report presents the results of that review.

The primary purpose of our review of Ameren Missouri's energy savings equations was to determine if they properly capture all of the factors needed to calculate kWh savings in accordance with commonly applied engineering principles and practices. In conducting its review of measure savings estimates, GDS compared savings estimates from Ameren Missouri's TRM to savings estimates from other TRMs. The purpose of this comparison was to identify measure savings values in the Ameren Missouri TRM that warrant further review because they fall outside the range of savings estimates from other TRM. The budget for this project did not allow for any building simulation modeling for the purpose of verifying weather sensitive savings estimates, or a review of building simulations conducted by Ameren Missouri.

Section 2 of this report presents results of the GDS review for each energy savings equation in the Ameren Missouri TRM. In Section 3 GDS summarizes its findings regarding the Ameren Missouri TRM savings equations, presents summary savings estimate comparison tables and provides its recommendation regarding whether the Ameren Missouri TRM should be: (1) accepted in its current form, (2) rejected as inadequate, or (3) accepted with conditions.

In addition to this report GDS also provided MDNR Excel spreadsheets containing all of the energy savings data collected from other TRMs and all of the comparative analysis.

[1] Appendix A, Technical Resource Manual, 2012 Energy Efficiency Filing

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2.0 REVIEW OF ENERGY SAVINGS EQUATIONS

This section of the report presents findings with regard to the energy savings equations presented in Ameren Missouri's TRM. Each equation was reviewed by GDS to determine if it properly captures all of the factors needed to calculate kWh savings in accordance with commonly applied engineering principles and practices. Where appropriate, revised or alternative equation formulations are recommended.

2.1 Residential Lighting

The residential lighting savings equation on page 5 of the Ameren Missouri TRM does not account for additional cooling savings associated with reduced lighting wattage or in service rate. An "in-service" rate is used to reflect the fact that not all lighting products purchased are actually installed. A more appropriate form of this equation is:

$$\Delta kWh = \frac{(Base\ Watts - Efficient\ Watts)\ x\ HOU\ x\ 365}{1000}\ x\ ISR\ x\ WHF_e$$

Where:

ISR = In service rate, or the percentage of units rebated that actually get used.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting.[2]

HOU = Average hours of use per day

Energy efficient lighting also impacts heating use. The following equation could be used to account for increased heating use:

$$\Delta MMBTU = (\Delta kWh / WHF_e)\ x\ .003413\ x\ AR\ x\ HF /\ EF$$

Where:

ΔMMBTU = Increased annual heating MMBTU usage from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

AR = Typical aspect ratio factor. ASHRAE heating factor applies to perimeter zone heat therefore it must be adjusted to account for lighting in core zones. The assumed aspect ratio for residential buildings is 100%.

HF = ASHRAE heating factor for lighting waste heat.[3]

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[2] For example, the Mid-Atlantic Technical Reference Manual, Version2.0, July 2011 shows the following waste heat factor calculation on pages 16 and 17. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc.). Assuming 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

EF = Average heating system efficiency

2.2 Residential HVAC

The energy savings equation show on page 7 of the Ameren Missouri TRM for early replacement HVAC applications is just a statement of fact that the savings = base use less efficient use. Instead the TRM should include the equation form shown on page 10 of the March 2011 Check Me program evaluation.[4] For use in an early replacement application, that equation would be as follows:

$$\Delta kWh = EFLH\ x\ \frac{kBTU}{hr}\ x\ \frac{\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}}{1000W/kW}$$

Where:

EFLH = Equivalent full load hours

kBTU/hr = The nominal rating of the capacity of the AC unit in kBTU/hr. 1 Ton = 12 kBTU/hr

$SEER_{base}$ = Seasonal energy efficiency ratio of the equipment being replaced (BTU/Wh)

$SEER_{ee}$ = Seasonal energy efficiency ratio of the energy efficient equipment (BTU/Wh)

For a replace on failure scenario the $SEER_{base}$ would not be the SEER of the failed unit. Instead it would be defined as the unit that would typically be installed in the absence of a utility program. In the Ameren Missouri TRM this is defined as a SEER 13 unit for central air conditioning.[5]

2.3 Residential Appliances

Appliance Recycling

The following equation shown on page 29 of the Ameren Missouri TRM is appropriate assuming that the average in unit energy consumption (UEC) of the type of equipment that is being removed is known for the Ameren Missouri service area.

$$\Delta kWh = (Base\ UEC\text{-}\ Efficient\ UEC)\ x\ AdjustmentFactor$$

Where:

UEC = Average unit energy consumption

[3] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993. Heating factor differs for residential and commercial applications. See table below for HF in each application.
[4] CheckMe® Plus Program Evaluation (Program Year 1, 2010), Final Report (Revised Draft), Prepared by the Cadmus Group for Ameren Missouri, March 2011.
[5] Appendix A, Ameren Missouri Technical Resource Manual, 2012 Energy Efficiency Filing, p. 8.

Adjustment Factor = Factor considering appliances not plugged in year-round (also known as partuse)

Otherwise an additional in situ adjustment factor should be applied. The in situ adjustment captures the impact on consumption of factors such as household size, location of the unit or climate, if the average consumption estimate is from a different climate region. Ohio uses a single in situ adjustment factor in their TRM that includes climate differences, while Vermont uses two adjustment factors, one for in situ usage and the other for temperature of the appliance location. Both also use an adjustment factor to capture the impact of partial appliance use.

Energy Star Refrigerator

The equation on page 30 of the Ameren Missouri TRM that is identified as the change in use equation for Energy Star refrigerators is an equation that is typically included in TRMs.

$$\Delta kWh = Base\ UEC - Efficient\ UEC$$

Where:

UEC = Average unit energy consumption

It is noted in the Ameren Missouri TRM that *"If the appropriate field data required to complete this equation cannot be obtained, the deemed savings values in the table are to be used for each measure."*

It is unlikely that base consumption and energy efficient refrigerator assumption can be reliably acquired in the field without metering, therefore this equation is simply statement of fact that kWh savings is equal to the difference between consumption of the determined base unit and energy efficient unit. Therefore it is critical that the deemed savings values that will be used are from a recent Ameren Missouri EMV report. This is the case, according to Ameren Missouri, as the estimated savings credit for Energy Star refrigerators of 1,126 kWh is taken from an Ameren Missouri PY2 EMV Report. However, it should be noted that the estimated savings credit is from an impact evaluation of Ameren Missouri's 2010 Multi-Family Income Qualified Program (MFIQ) and therefore may not be an appropriate estimate to apply to other programs that target single family homes or are not income limited.[6] Factors that can affect refrigerator energy use that may be correlated with income include family size, number of meals eaten out of the home, refrigerator age, size and features.

Smart Strip Plug Outlet

The following equation for a smart strip plug outlet from page 31 of the Ameren Missouri TRM is correctly stated:

[6] Multifamily Income-Qualified Program Evaluation Program Year 2, 2010, Final Report, Prepared by the Cadmus Group for Ameren Missouri, April 2011, p. 3.

$$\Delta kWh = \frac{(Base\ Idle\ Watts - Efficient\ Idle\ Watts)\ x\ Idle\ Hours\ per\ day\ x\ 365}{1000}$$

The Key Assumptions as stated in the TRM for the above equation are:

- Idle Watts = average energy used by system when in standby mode and computer or TV is turned off= 0
- Idle Hours per day= hours per day when system is assumed to be turned off= 19.5

"Idle Watts" should be restated so that the "Efficient Idle Watts" for equipment plugged into the Smart Strip is equal to 0. Consumer electronics consume a significant amount of energy they operate in low-power modes but are not actually in use. One way to reduce this unnecessary electricity consumption is to use smart plug strips, which automatically turn off plug loads when not in use.

Pool Pump and Motor

The following equation for a **single speed high efficiency pool pump** from page 31 of the Ameren Missouri TRM is not correct:

$$\Delta kWh = \frac{\Delta HP\ x\ \Delta LF}{\Delta PME}\ x\ CF\ x\ AOH$$

Deltas cannot be used in this formula because the denominators (PME) used to calculate base and efficient pump use are not the same. If ∆HP or ∆LF =0, then the formula will produce a zero value. The formula should be as follows:[7]

Single Speed High Efficiency Pool Pump Energy Savings

$kWhBase = (HP * LFBase * 0.746) / \eta PumpBase * Hrs/dayBase * Days/yr$

$kWhEff = (HP * LFEff * 0.746) / \eta PumpEff * Hrs/dayEff * Days/yr$

$\Delta kWh = kWhBase - kWhEff$

Where:

HP = Horsepower of motors

LFBase = Load factor of baseline motor

LFEff = Load factor of efficient motor

ηPumpBase = Efficiency of baseline motor

ηPumpEff = Efficiency of high efficiency motor

Hrs/day = Assumed hours of pump operation per day

Days/yr = Assumed number of days pool in use

[7] Ohio TRM, August 6, 2010, pp. 120 -121.

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The following equation for a **two speed high efficiency pool pump** from page 32 of the Ameren Missouri TRM is also incorrectly correctly stated for the same reasons discussed above.

$$\Delta kWh = \frac{\Delta HP1\ x\ \Delta LF1}{\Delta PME1}\ x\ CF\ x\ AOH1 + \frac{\Delta HP2\ x\ \Delta LF2}{\Delta PME2}\ x\ CF\ x\ AOH2$$

The formula should be shown as follows:

Two Speed High Efficiency Pool Pump Energy Savings

kWhBase = *(HP * LFBase * 0.746) /ηPumpBase * AOHBase*

kWhEff = *(HP * LFEff1 * 0.746) /ηPumpEff1 * AOHEff1 + (HP * LFEff2 * 0.746) /ηPumpEff2 * AOHEff2*

ΔkWh = *kWhBase - kWhEff*

Where:

HP = Horsepower of motors

LFBase = Load factor of baseline motor

LFEff1 = Load factor of two speed motor at slow speed

LFEff2 = Load factor of two speed motor at high speed

ηPumpBase = Efficiency of baseline motor

ηPumpEff1 = Efficiency of two speed motor at slow speed

ηPumpEff2 = Efficiency of two speed motor at high speed

AOHBase = Assumed annual operating hours of baseline pump

AOHEff1 = Assumed annual hours of two speed pump at low speed

AOHEff2 = Assumed annual hours of two speed pump at high speed

<u>Variable Frequency Drive (VFD) on Swimming Pool Pump</u>

The equation for calculation energy savings for a VFD on a pool pump is shown on page 33 of the Ameren Missouri TRM. It includes a BaseCF and EfficiencyCF where CF is defined as a Control Factor. This term is not defined in the TRM.

$$\Delta kWh = \frac{(BaseCF - EfficientCF)\ x\ Conversion\ Factor\ x\ Motor\ HP\ x\ FL\ x\ HOU\ x\ 365}{Motor\ Efficiency}$$

In centrifugal pool pumps, energy consumption is proportional to the cube of the flow rate. That means that a motor running at 50% of full speed capacity has a motor torque of 25% of full speed and the electricity required to operate the motor is 12.5% of the amount of electricity

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required if the motor was running at full speed. It is unclear how this is captured through the Control Factor.

2.4 Residential Building Shell

There are no savings equations identified in Ameren Missouri's TRM for residential building shell measures, Instead, it states on page 33 that the savings values for residential building shell measures (referring to Single Family Window Replacement, Multi Family Window Replacement and Multi Family Window Film) were developed using building simulations. The energy savings values in the data tables for each of these measures also reference footnote "1" as a source, but no there is no corresponding footnote. It also is not clear how a single savings value for each building shell measure was developed. The Building Simulation Protocols section of the TRM states on page 91 that Ameren Missouri has a database that allows it to apply population weights for climate zone, building type and vintage to compile weighted savings values. However, there is no description of the specific weighting algorithm that was used to develop the deemed saving values for residential building shell measures or key assumptions such as heating and cooling degrees days and/or full load heating/cooling hours. Also, the estimated savings credits for residential building shell measures contain no detail on whether they include heating as well as cooling savings or other related ancillary HVAC system savings associated with pumps, fans and motors.

2.5 Residential Water Heating

Water Heater

On page 34 of the Ameren Missouri TRM the residential water heating energy savings formula is listed as:

$$\Delta kWh = \frac{(Efficient\ EF - \ Base\ EF)\ x\ (HWT - CWT)\ x\ 8.3\ x\ GPD\ x\ 365}{(Efficient\ EF - \ Base\ EF)\ x\ 3413}$$

This formula is not correct. The (Efficient EF – Base EF) factor is repeated in both the numerator and denominator, which cancel out this factor. Also the impact of the difference in water heater efficiency factors is appropriately captured by the difference between the reciprocals of the base EF and the efficient EF. The Pennsylvania TRM utilizes the following formula to determine kWh savings from High Efficiency Hot Water Heaters:[8]

$$\Delta kWh = \frac{\left\{\left(\frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}}\right) \times \left(HW \times 365 \times 8.3\,\frac{lb}{gal} \times (T_{hot} - T_{cold})\right)\right\}}{3413\,\frac{Btu}{kWh}}$$

Where:

HW = GPD (Gallons per day).

[8] State of Pennsylvania, Technical Reference Manual, June 2012, p. 20.

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EFbase = Energy Factor of baseline water heater

EFproposed = Energy Factor of proposed efficient water heater

T_{hot} = Temperature of hot water

T_{cold} = Temperature of cold water supply

When this formula is used with the given Ameren water heater input assumptions, the estimated 157 kWh savings credit shown on page 35 of the Ameren Missouri TRM can be verified. For this calculation GDS assumed 64.3 GPD, which appears to be incorrectly identified in the Ameren Missouri as an Energy Factor.[9]

Water Heater Blanket

The water heater blanket savings equation on page 35 of the Ameren Missouri TRM is not theoretically correct. It assumes a thermal efficiency of the electric heater element of 100%. There should be a thermal efficiency coefficient in the denominator. In the Pennslyvania TRM, the thermal efficiency of an electric heater element is assumed to be 97%[10]. The revised equation would read as follows:

$$\Delta kWh = \frac{\Delta UA \; x \; 8760 \; x \; \Delta Temp}{3413 \; x \; n_{Elec}}$$

Where:

UA = Difference between overall heat loss coefficient of the baseline water heater and the overall heat loss with the wrap installed

ΔTemp = Difference between the temperature setpoint of the water heater and the ambient air temperature

8760 = Number of hours in a year

3413 = Conversion factor

η_{Elec} = Thermal efficiency of electric heater element

Pipe Wrap

The following pipe wrap energy savings equation on page 37 of the Ameren Missouri TRM is appropriate if the heat loss per linear foot of pipe is known.

$$\Delta kWh = Heat\ Loss \text{ x } Length\ of\ Pipe$$

The TRM cites PY2 EMV Results as the source for a heat loss estimate of 28 kWh per linear foot for multifamily dwellings, but this is actually only applicable for participants in Ameren

[9] Appendix A, Ameren Missouri Technical Resource Manual, 2012 Energy Efficiency Filing, p. 34.

[10] State of Pennsylvania, Technical Reference Manual, June 2012, p. 135. The original source of this assumption is: New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. October 15, 2010. Prepared by New York Advisory Contractor Team.

Missouri's Multi-Family Income Qualified Program (MFIQ).[11] No estimate of heat loss per linear foot is provided for non-income qualified multi-family dwellings or single family dwellings. However an annual savings estimate of 257 kWh per 10 linear feet is provided for single family dwellings. The cited source for this estimate is the Morgan Measure Libraries.

A more detailed form of the above equation that does not require a valid heat loss per linear foot estimate is as follows:[12]

$$\Delta kWh = ((1/Rexist - 1/Rnew) \text{ x } (Length * Circumference) \text{ x } \Delta T \text{ x } 8{,}760) / \eta DHW / 3413$$

Where:

Rexist = Assumed R-value of existing uninsulated piping = 1.0[13]

Rnew = R-value of existing pipe plus installed insulation

Length = Length of piping insulated

Circumference = Circumference of piping (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)

ΔT = Temperature difference between water in pipe and ambient air

8,760 = Hours per year

ηDHW = DHW Recovery efficiency (ηDHW) = 0.98

3413 = Conversion from Btu to kWh

Low Flow Showerhead

The energy savings equation for low flow showerhead on page 37 of the Ameren Missouri TRM was taken from Ameren Missouri's Multifamily PY2 Report.[14]

$$\Delta kWh = \frac{Number\ of\ People\ x\ ST\ x\ Days\ x\ \Delta GPM\ x\ \Delta Temp}{409.7\ x\ EF\ x\ Number\ of\ Units}$$

Where:

Number of People = Number of people in dwelling

ST = Shower time in minutes

Days = Number of days per year a shower is taken

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[11] Multifamily Income-Qualified Program Evaluation Program Year 2, 2010, Final Report, Prepared by the Cadmus Group for Ameren Missouri, April 2011, p. 28.

[12] Mid-Atlantic Technical Reference Manual, Version2.0, July 2011, pp. 86-87.

[13] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77, presented to the Ontario Energy Board: http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[14] Multifamily Income-Qualified Program Evaluation Program Year 2, 2010, Final Report, Prepared by the Cadmus Group for Ameren Missouri, April 2011, p. 28.

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ΔGPM	= Difference in gallons per minute for the base showerhead and the new showerhead
ΔTemp	= Difference in temperatures of the shower water and the water main
EF	= Energy factor of the water heater
Number of Units	= Number of showerheads in home
409.7	= A constant derived from 3,413/8.33

This is an appropriate equation for estimating electric water heater kWh savings associated with installation of a low flow showerheads. However, the assumed number of units is not provided in the TRM or the Multifamily PY2 Report.

Low Flow Faucet Aerators

The energy savings equation for low flow faucet aerators on page 38 of the Ameren Missouri TRM was taken from Ameren Missouri's Multifamily PY2 Report.[15]

$$\Delta kWh = \frac{Number\ of\ People\ x\ FT\ x\ Days\ x\ \Delta GPM\ x\ \Delta Temp}{409.7\ x\ EF\ x\ Number\ of\ Units}$$

This is an appropriate equation for estimating electric water heater kWh savings associated with installation of a low flow faucet aerators. However several of the definitions for parameters in this equation as stated in the TRM are incorrect. (See the proposed revisions in parenthesis below)

Where:

Number of People = number of people in dwelling

FT =faucet time in minutes

Days = number of days per year a shower is taken *(This should read: number of days per year that the faucet is used)*

GPM = difference in gallons per minute for the base showerhead and the new showerhead *(This should read: difference in gallons per minute for the base faucet aerator and the new faucet aerator)*

Temp =difference in temperatures of the shower water and the water main *(This should read: difference in temperatures of the cold intake water and faucet water)*

EF = energy factor of the water heater

[15] Multifamily Income-Qualified Program Evaluation Program Year 2, 2010, Final Report, Prepared by the Cadmus Group for Ameren Missouri, April 2011, p. 29.

Number of Units = number of faucets in home

• 409.7 = a constant derived from 3,413/8.33

• CF =Coincident Factor= 0.70 *(Coincidence Factor is not used in this equation)*

2.6 Commercial Lighting

Lamps & Fixtures

The following commercial lighting savings formula shown on pages 40-49 of Ameren Missouri's TRM, is appropriate.

$$\Delta kWh = (Watts_{base} - Watts_{ee})\ x\ HOURS\ x\ IF/1000$$

Where:

IF = Interactive Factor

$WATTS_{base}$ = Power draw (expressed in Watts) of base (existing) electrical equipment

$WATTS_{ee}$ = Power draw (expressed in Watts) of efficient (replacement) electrical equipment

HOURS = annual operating hours

It is stated in the TRM (pages 40 – 49) that the interactive factor is assumed to be 1 for the first 3 year implementation program until further data can be gathered and consensus can be built. Ameren Missouri may be able to estimate a value for this factor using the prototype building simulations for commercial buildings that are described in the TRM.[16]

Also, with regard to the annual operating hours shown in the following table from p. 39 of the TRM. It references the PY 2 EMV report conducted by ADM Associates, Inc. 2011.[17] GDS could not find any of these values in the report.

[16] Appendix A, Ameren Missouri Technical Resource Manual, 2012 Energy Efficiency Filing, pp. 104 - 130.
[17] Evaluation of Business Energy Efficiency Program Custom and Standard Incentives, October 2009 Through September 2010, March 2011, Prepared by ADM

Interior Lighting Operating Hours by Building Type		
Building Type	Annual Hours	Building Mix Weighting**
Assembly	5,397	4.2%
Big Box Retail	6,439	4.0%
Fast Food Restaurant	6,492	2.4%
Full Service Restaurant	4,850	1.2%
Grocery	6,702	6.2%
Hospital	3,758	5.9%
Hotel	8,760*	1.7%
Large Office	5,571	11.3%
Light Industrial	5,594	43.0%
Primary School	3,149	7.2%
Small Office	4,342	5.6%
Small Retail	4,883	2.0%
Warehouse	5,063	5.3%
Weighted Average	5,202	100%

Source: From Ameren Missouri PY 2 EMV report conducted by ADM Associates, Inc. 2011
*Non-Guest Room
** Weights taken from Morgan Measure Database

The above table shows a weighted average operating hours of 5,202 which is different than assumed annual operating hours used for some of the lighting measures such as the 4,160 hours shown on page 40 and 3680 hours shown on page 47 of the TRM. There is no source cited in the TRM for these operating hours.

<u>Lighting Controls</u>

The following commercial lighting controls savings formula shown on pages 50 of Ameren Missouri's TRM, is appropriate if the SF term in the equation is defined as square feet of controlled lighting space instead of square feet in a room.

$$\Delta kWh = \frac{SF\ x \frac{watt}{SF}\ x\ hours\ x\ \%reduction}{1000}$$

Where:

SF = square feet

Watt/SF = watt per square feet of controlled lighting space
%reduction = percentage of energy reduction attributed to lighting control fixture

Another form of this equation that would likely be more accurate, if actual field data is available, is as follows:

$$\Delta kWh = \frac{WattsControlled\ x\ hours\ x\ \%reduction}{1000}$$

Where:

WattsControlled = Total watts controlled by each type of sensor.

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2.7 Commercial Cooking Equipment

Energy Star Steam Cooker

The Energy Star Steam Cooker savings formula on page 51 of Ameren Missouri's TRM is not correct. It is missing two key parameters: "Operating days per year" and "Percent of Time in Manual Mode. "

Operating days per year = The number of days in the year that the equipment operates

Percent Time in Manual Mode = The average amount of time per day the steamer is operated in manual (constant steam) mode, without the use of a cooking timer that switches the steamer into standby mode. Expressed as a percentage of total hours operated per day (%).

The correct equations are as follows:

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

$$kWh = \left(\left(LB\ x\ \frac{E_{Food}}{EFF} + \left((1 - PTMM)\ x\ IDLE + \left(PTMM * PC * \frac{E_{Food}}{EFF} \right) \right) * \left(HOURS_{Day} - \frac{LB}{PC} - \frac{PRE_{Time}}{60} \right) + PRE_{Energy} \right) x\ DAYS$$

Where:

kWh_{base}	= Annual energy usage of the baseline equipment calculated using baseline values
kWh_{eff}	= the annual energy usage of the efficient equipment calculated using efficient values
LB	= Pounds of food cooked per day (lb/day)
EFF	= Heavy load cooking energy efficiency (%)
E_{Food}	= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food = 0.038564
PTMM	= The average amount of time per day the steamer is operated in manual (constant steam) mode. Expressed as a percentage of total hours operated per day (%).
IDLE	= Idle energy rate
$HOURS_{Day}$	= Daily operating hours
PC	= Production capacity (lbs/hr)
PRE_{Time}	= Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on
PRE_{Energy}	= Preheat energy (kWh/day)
DAYS	= Operating days per year

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The above equation will replicate the results from the Electric Steam Cooker Savings Calculators that can be found on the Food Service Technology Center and Energy Star Websites.[18]

Energy Star Hot Food Holding Cabinet

The following Energy Star Hot Food Holding Cabinet energy savings formula on page 51 of the Ameren Missouri TRM is correct

$$\Delta kWh = \frac{InternalVolume\ x\ (\frac{\Delta Watts}{Volume})\ x\ (\frac{Hours}{Year})}{1000}$$

2.8 Commercial Refrigeration

Energy Star Ice Machines

The following energy savings formula for Energy Star Ice energy savings on page 56 of the Ameren Missouri TRM is correctly stated. However, the terms in the equation should be more clearly defined. Currently only a Load Factor (LF) is provided, but the term is not defined.

$$\Delta kWh = \frac{kWh\ base}{100lbs} - \frac{kWh\ eff}{100lbs}\ x\ \frac{lbs/24hrs}{100lbs} x\ 365\ x\ LF$$

GDS recommends that the following descriptions be added to the TRM for this equation:

Where:

kWh base/100lbs = Energy consumption of base efficiency machine per 100 lbs.

kWh eff/100lbs = Energy consumption of high efficiency machine per 100 lbs.

lbs⁄24hrs = Ice Harvest Rate

LF = Pounds of Ice Used per Day/Ice Harvest Rate

Anti-Sweat Heater Controls

The following Anti-Sweat Heater Controls savings formula on page 57 of the Ameren Missouri TRM is correct. However, the term kWbase should be identified as a key assumption and a definition should be provided as shown below:

$$\Delta kWh = kWbase\ x\ Numdoors\ x\ ESF\ x\ BF$$

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[18] http://fishnick.com/saveenergy/tools/calculators/esteamercalc.php
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CKP
(Commercial Kitchen Equipment Savings Calculator)

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kWbase = Connected load kW for typical reach-in refrigerator or freezer door and frame with a heater.

Beverage Vending Machine Controls

The energy savings formula for Beverage Machine Controls in the Ameren Missouri TRM is an appropriate formula, but savings, based on actual field data could be more precisely calculated using an alternative approach that takes into consideration nameplate information and assumptions regarding the duty cycle of the equipment.

The formula as stated on page 57 of the Ameren Missouri is as follows:

$$kWh = 8760\, x \frac{WATTS}{1000} x\, ESF$$

Where:

ESF = Energy Savings Factor = 35% (per Morgan Measure Library)

WATTSbase = 536.85 watts per unit

An alternative approach for calculating Beverage Machine Control Savings can be found in the New York and Massachusetts TRMs.[19] Both take into consideration actual nameplate equipment data and the equipment duty cycle. Presented below is the more detailed equation found in the New York TRM, which considers the duty cycle during winter and non-winter month nights. The controls are assumed to allow the machines to be turned on and reach desired temperatures during the hours of business operations, but turned off during other times. The Massachusetts TRM uses a single weighted average annual duty cycle.

NY TRM Savings Estimation Approach – Vending Machine Central Controls

*∆kWh = (Demand of Novelty Cooler) * ((0.45 * (hrs off/day * 91 days)) + (0.50 * (hrs off/day * 274 days)))*

Where:

Demand of Novelty Cooler = Total demand of Novelty Cooler, based on nameplate Volts and Amps, Phase, and Power Factor .

0.45= Duty cycle during winter month nights, based on vendor estimates

Hrs off/day = Potential off hours per night. Calculated as, number of hours store closed per day minus one (controller turns unit back on one hour before store opens).

91 days = Number of days in winter months

0.50 = Duty cycle during non-winter month nights, based on vendor estimates

274 days = Number of days in non-winter months.

Power Factor = 0.85

[19] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, October 15, 2010, p. 188; Massachusetts TRM, October 2010, p. 198.

Efficient Refrigeration Condenser

The energy savings formula for an Efficient Refrigeration Condenser on page 58 of the Ameren Missouri TRM is correct. However, GDS was unable to precisely replicate the deemed savings value of 120 kWh /ton based on the key assumptions provided in the TRM. This may be due to rounding of the average load percentages shown in the TRM.

$$\Delta kWh = Tons\ x\ \Delta Average\ Annual\ Load\ x\ \Delta FLE\ x\ \Delta FLH$$

Where:
FLH = Full Load Hours = 4,380 hours

System Capacity= Full Load= 2.3 kW/ton at 105°F saturated condensing temp.

Average Annual Load

- Baseline (10°F condenser approach) operating based on 82F ambient had an average. load of 82%; based on 70F ambient had an average. load of 79%
- Efficient (7°F condenser approach) operating based on 82F ambient had an average. load of 83%; based on 70F ambient had an average. load of 80%

FLE = Full Load Efficiency

- Baseline. based on 82F 1.92 kW/ton; based on 70F 1.85 kW/ton
- Efficient based on 82F 1.86 kW/ton; based on 70F 1.78 kW/ton

2.9 Commercial Hot Water Measures

Heat Pump Water Heaters

The following formula for Heat Pump Water Heaters on page 59 of the Ameren Missouri TRM was taken from the Ohio TRM with the addition of the Diversity Factor (DF) variable from the Morgan Measure Libraries.[20] Because DF is not defined it is unclear what its purpose is in the kWh savings equation. Such a diversity factor would typically be used to reflect the impact on kW demand of the diversity of operation between multiple water heating units. For example a diversity factor is applied to the kW savings equation in the NY TRM.[21]

$$\Delta kWh = \frac{GPD\ x\ Days\ per\ year\ x\ 8.33\ x\ DF\ x\ \Delta Ts}{3413}\ x\ \left(\frac{1}{E_{(t,base)}}\right) - \left(\frac{1}{COP}\right))$$

Key Assumptions::

- $E_{(t,base)}$: Thermal efficiency of a standard commercial electric water heater: 98%
- COP of an ASHP water heater: 3.5

[20] Appendix A, Ameren Missouri Technical Resource Manual, 2012 Energy Efficiency Filing, p. 60
[21] NY TRM, September 29,2010, p. 160.

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- Cost estimates include installation.
- 77°F temperature difference from makeup water to hot water supply (Standard US DOE Test Procedure)
- Diversity Factor (DF): 0.65
- Heaters are generally located in unconditioned spaces
- 360 days per year
- Et Base: Thermal efficiency of existing unit

Pre-Rinse Spray Valves

The following formula for Pre-Rinse Spray Valves on page 60 of the Ameren Missouri TRM produces results that a very similar to those that GDS derived from the Food Service Technology Center's Pre-Rinse Spray Valve Calculator. Those differences are likely due to rounding of inputs.

$$\Delta kWh = \Delta Flow\ Rate\ x\ 8.3\ x \frac{Hrs}{wk} x\ 60\ x\ 52\ x\ (\Delta Temp) x (\frac{29.3}{EF\ water\ heater})/100000$$

Key Assumptions:

- Cold Water Supply Temperature: 60°F, Hot Water Supply Temperature (from sprayer) of 128°F
- Average use of 5.1 hour per week (approximately 265.20 hours per year)
- Assumes 100% EF water heater
- Baseline GPM assumed to be 2. 78 GPM

Low Flow Faucet Aerators

The following formula for Low Flow Faucet Aerators on page 60 of the Ameren Missouri TRM is correct. However, no source is provided to support the assumptions used to calculate the value of annual flow rate savings (See Q below under Key Assumptions). This is a key savings equation input.

$$\Delta kWh = (Q\ x\ 8.33\ xT_d)/3413/EF$$

Key Assumptions:

- Q = flow rate savings, gallons per year =1 ,048 gallons/yr =.1GPM * 1 min per use* 365 days* 5.74 persons I 2 fixtures
- 8.33 = conversion factor (Btu/gal-°F)
- Td = Temperature difference between hot water setting and makeup water temperature = 68°F
- EF = Efficiency of electric water heater = 1 00%
- 3,413 = Btu per kWh

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2.10 Commercial Motors and Drives

Commercial Pumps for Process

GDS is unable to determine the validity of the following energy savings formula for Commercial Pumps for Process on page 61 of the Ameren Missouri TRM. It is not clear how the fixed energy savings factor (ESF) of 15% was derived and no values are provided for pump efficiency. Using the assumption provided in the TRM, we could replicate any of the savings values shown on page 62 of the TRM.

$$\Delta kWh = (HPmotor\ x\ LF\ x\ 0.746/\eta motor)\ x\ HOURS\ x\ (ESF/\eta pump)$$

Key Assumptions:

- 3680 hours of operation
- Load Factor = LF = 76%.
- $\eta motor$ = Motor efficiency = 90%
- $\eta pump$ = pump efficiency
- ESF = Energy Savings Factor = 15%

It is not clear why Ameren Missouri did not use a more classical approach for estimating pump savings, when the "before" and "after" pump system efficiencies are known. That equation would be as follows:

Annual Energy Savings (kWh) = kW x t x (1 – η1/ η2)

Where:

kW = Input kW for pump drive motor under original operating conditions

t = Annual pump operating hours (Note: kW x t is the baseline pumping system energy use)

η1 = Efficiency of the original pumping system, %

η2 = Efficiency of the improved pumping system, %

Commercial Variable Frequency Drives for Process Pumping

The following energy savings equation for Commercial Variable Frequency Drives for Process Pumping on page 63 of the Ameren Missouri TRM is missing a .746 conversion factor unless BHP is stated in kW. Also, there are no input values provided in the TRM for the Energy Savings Factor (ESF).

$$\Delta kWh = (BHP/\eta motor)\ x\ HOURS\ x\ ESF$$

Key Assumptions:

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- Hours of operation = see chart below
- The average loading of the pumps analyzed was 86% pump capacity.
- Coincidence Factor (CF) = 0.78
- BHP = Brake horsepower of motor, should be collected with application.
- 11motor = efficiency of motor being driven by VFD = 59%

2.11 Commercial HVAC Applications

Chillers

The following commercial chillers savings formula is applied to chiller measures on pages 65 - 67 of Ameren Missouri's TRM.

$$\Delta kWh = T(OH)\ x\ (\eta_{Ex-}n_{Ret})$$

Key Assumptions:

IPLV = Integrated Part Load Factor. The term IPLV is used to signify the cooling efficiency related to a typical (hypothetical) season rather than a single rated condition. The IPLV is calculated by determining the weighted average efficiency at part-load capacities specified by an accepted standard

η_{Ex} = Efficiency of existing chiller at given part load condition, or IPLV (0.63 kW/ton)

n_{Ret} = Full load efficiency for retrofit chiller (0.51 kW/ton)

T = Capacity of chiller (tons) (assumed 560 tons)

OH = Equivalent full load annual operating hours (hr)

It is not clear to GDS why Ameren Missouri has chosen to use the part load efficiency to define the efficiency of the existing chiller and full load efficiency to define the efficiency of the new chiller. For example, the Vermont TRM uses the following chiller savings equation:

$$\Delta kWh = tons\ x\ (IPLVbase - IPLVee)\ x\ FLH$$

Where:

IPLVbase = Integrated part load value efficiency of the baseline chiller (kW/ton)

IPLVee = Integrated part load value efficiency of the energy efficient chiller (kW/ton)

FLH = OH = Full load hours

Unitary and Heat Pump Systems

The following energy savings formula is applied to all Unitary and Heat Pump Systems on pages 67 - 72 of Ameren Missouri's TRM.

$$\Delta kWh = (BtuH/1000)\ x\ (1/EERb – 1/EERq)\ x\ EFLH$$

Key Assumptions:

BtuH = Cooling capacity in Btu/Hour

EERb = Efficiency rating of the baseline unit.

EERq = Efficiency rating of the High Efficiency unit.

EFLH =Equivalent Full Load Hours- This represents a measure of energy use by season during the on-peak and off peak periods. This value will be determined by existing measured data of kWh during the period divided by kW at design conditions

The above equation is appropriate for calculating energy savings for unitary HVAC units. However for heat pumps a more common approach would be to use the above equation for calculating cooling savings and use the Heating Seasonal Performance Factor (HSPF), as a replacement for EER in the above equation, to calculate heating savings. This is mentioned in the under Key Assumptions for each of the Heat Pump measures, but then a single EER value is provided. So it is not clear if this equation and the Key Assumptions as written will correctly quantify heat pump savings.

Guest Room Energy Management System

The following equation for calculating savings associated with Guest Room Energy Management Systems is provided on page 73 of the Ameren Missouri TRM. It appears that this equation is appropriately capturing all of the factors in a form that is necessary to calculate HVAC energy savings. However In some applications where lighting is also controlled, these additional savings should be included. Also, a source should be provided for the assumed 30% Energy Savings Factor (ESF), the cooling/heating correction factors should be defined, and a purpose and description of the (12/9.7) term is needed.

$$\Delta kWh = \frac{\left[\frac{BTU*(1-OPC)}{Cooling\ design\ temp - room\ setpoint\ temp} * CDD * 24 * CCF\right]}{12000} * \left(\frac{12}{9.7}\right) + \left[\frac{BTU*(1-OPH)}{room\ setpoint\ temp\ - heating\ design\ temp} * HDD * 24 * HCF * ESF\right.$$

Key Assumptions:

Assumes 30% energy savings over baseline.

CCF = cooling correction factor= 1

HCF = heating correction factor = 0. 75

ESF =energy savings factor= 30%

BTU= BTU per ton= 12,000 *size of unit (tons)

Example: 1 ton unit= 12,000 BTU* 1 ton= 12,000

OPC = oversized percentage cooling = 15%

OPH = oversized percentage heating = 15%

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CDD = annual cooling degree days = 1295

HDD = annual heating degree days = 5329

Cooling Design Temp= 91 F

Heating Design Temp= 7F

Room Setpoint Temp= 71 F

2.12 Commercial Miscellaneous

Tractor Heater Timers

The following energy savings equation for Tractor Heater Timers can be found on page 74 of the Ameren Missouri TRM. This equation is appropriate for calculating energy savings for this measure.

$$\Delta kWh = \frac{P\ x\ hours\ x\ days\ x\ UF}{1000}$$

Key Assumptions:

P = average power of engine block heater = 1,000 watts

Hours = reduction in hours block heater is used = 8 hours

Days = number of operating days per year= 90 days

UF =usage fraction= 0.8

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3.0 SUMMARY OF FINDINGS AND RECOMMENDATION

This section of the report summarizes the findings of our review of energy savings equations and energy savings estimates presented in Ameren Missouri's TRM.

3.1 Review of Energy Savings Equations

A summary of the GDS analysis of energy savings equations is presented in Tables 3.1.1 and 3.1.2 for the Residential and Commercial & Industrial sectors, respectively. Issues found with the energy savings equations have been grouped into the following categories in the summary tables:

Equation Summary Tables - Definitions

(1) **Incorrect Equation:** The equation as presented in the TRM will not correctly calculate measure savings

(2) **Interactive Effects Not Included:** The impact of installing the measure on energy consumption by other end-uses is not included in the equation. For example, lighting measures also impact cooling and heating energy consumption.

(3) **In-Service Rate Not Included:** In service rate, or the percentage of units rebated that actually get used, is not included in the equation..

(4) **Non Calculative:** The equation represents a simple statement of fact (such as savings equals base use minus efficient use) instead of an engineering equation that will actually calculate base and efficient use based on key inputs such as equipment wattage, horsepower, operating hours, and efficiency ratings.

(5) **In-Situ Adjustment Factor Not Included:** An in situ adjustment factor which captures the impact on consumption of factors such as household size, location of the unit or climate is not included in the equation.

(6) **Key Assumptions Incorrectly Stated/Not Defined/Missing:** Key equation assumptions listed in the TRM are incorrectly stated, not defined or missing.

(7) **Key Assumption Source Missing:** The source for a key equation assumption such as an energy savings rate is not provided.

(8) **Alternative Equation Would Improve Precision:** The precision of savings estimates will be improved by using an alternative equation.

(9) **Other:** Other issues that do not fit into any of the above categories were found. Notes in the tables summarize these other issues.

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Table 3.1.1
Summary of Energy Savings Equation Findings
Residential Sector

Measure	Incorrect Equation	Interactive Effects Not Included	In-Service Rate Not Included	Non Calculative	In-Situ Adjustment Factor Not Included	Key Assumptions Incorrectly Stated/Not Defined/Missing	Other
Lighting		X	X				
HVAC				X			
Appliance Recycling					X		
Energy Star Refrigerator				X			X (Note 1)
Pool Pump and Motor	X						
VFD on Pool Pump						X	
Water Heater	X						
Water Heater Blanket	X						
Pipe Wrap							X (Note 2)
Low Flow Showerhead						X	
Low Flow Faucet Aerators						X	

Table Notes:

(1) Non-calculative equation is typical for refrigerators in TRMs. However, estimated savings credit is from Multi-Family Income Qualified Program impact evaluation report which may not be applicable for homes that are not income limited or single family homes.(See Section 2.3, p. 5 for additional detail)

(2) The equation requires an estimate of heat loss per linear foot of water heater pipe, which according to the TRM is taken from the Multi-Family Income Qualified Program impact evaluation report. This may not be appropriate for homes that are not income limited or single family homes. See Section 2.5, p. 10 for an alternative approach for calculating pipe wrap savings that does not require a priori knowledge of heat loss per linear foot of water heater pipe.

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Table 3.1.2
Summary of Energy Savings Equation Findings
Commercial & Industrial Sector

Measure	Incorrect Equation	Interactive Effects Not Included	Key Assumption Source Missing	Key Assumptions Incorrectly Stated/Not Defined/Missing	Alternative Equation Would Improve Precision	Other
Lamps & Fixtures		X (Note 1)				X (Note 2)
Lighting Controls				X (Note 3)		
Energy Star Steam Cooker	X					
Energy Star Ice Machine				X		
Anti-Sweat Heater Controls				X		
Beverage Vending Machine Controls					X	
Efficient Refrigeration Condenser						X (Note 4)
Heat Pump Water Heaters	X (Note 5)			X		
Low Flow Faucet Aerators			X			
Commercial Pumps for Process			X	X	X	
Commercial VFDs for Process Pumping	X			X		
Chillers	X (Note 6)					
Unitary & Heat Pump Systems	X (Note 7)					
Guest Room Energy Management System			X	X		X (Note 8)

Table Notes:

(1) An interactive factor is included in the equation, but the value is set to 1.0 for the first 3 year implementation program. (See Section 2.6, p.12)

(2) Operating hours provided in the table on p. 39 of the TRM could not be found in the referenced source, and not all of the weighted operating hours provided in the TRM for each measure match those shown in the table on p. 39. (See Section 2.6, pp. 12 – 13)

(3) Alternative equation form is also recommended. (See Section 2.6, p. 13)

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(4) GDS was unable to precisely replicate the estimated savings credit for this measure using the stated equation and assumptions provided in the TRM.

(5) Undefined parameter in the equation may need to be removed.

(6) This could also be a problem with an incorrectly defined key assumption. (See Section 2.11, p. 20)

(7) Problem is with Heat Pump equation

(8) Does not included potential for lighting savings.

3.2 Review of Deemed Energy Savings Values

A summary of the GDS analysis of deemed energy savings values is presented in the following tables. This analysis consisted of a comparison of energy savings values for each non-weather sensitive measure in the Ameren Missouri TRM to savings values for the same measure in other TRMs. In addition to the other TRMs referenced in the Ameren Missouri TRM (Ohio and Pennsylvania), GDS also reviewed and compiled energy savings values from the Massachusetts, Mid-Atlantic, New York, Texas and Vermont TRM.

Energy savings comparisons were not conducted for weather sensitive measures. These included the following measures as identified on page 2 of the Ameren Missouri TRM.

- HVAC measures (heat pumps, air conditioners, furnaces, chillers, etc.);
- Building shell (insulation, air sealing, duct sealing, windows, etc.);
- Thermostats;
- Energy Management Systems;
- Condensers;
- Other measures whose savings depend on weather

For all weather sensitive measures not included in program year 2 (October 2009 - September 2010) EMV reports, building simulation modeling was conducted by Morgan Marketing Partners to determine measures savings estimates. GDS agrees with Ameren Missouri that the building simulation approach is far more accurate for quantifying measure level energy savings values for weather sensitive measures.[22] Conducting additional building simulation analysis or detailed review of the building simulations conducted by Morgan marketing partners was beyond the scope of this project. GDS considered comparing Ameren Missouri's weather sensitive savings estimates to weather sensitive savings estimates from other TRMs, adjusted for weather differences. However such estimates were generally not available. The other non-building simulation option would require calculation of weather sensitive estimates for other states using TRM equations, which for HVAC measures requires knowledge of equivalent full load cooling hours. In many TRMs, estimates of equivalent full load cooling hours vary by weather zone and building type. Determining an average savings value would therefore require multiple calculations with appropriate weighting factors applied, for example, to determine average commercial sector savings for an HVAC measure. This was also beyond the scope of this project and would not be as accurate as reviewing the existing building simulations upon which the savings estimates are based and conducting new simulations, if necessary.

Also not included in our comparison of TRM savings values were the following measures in the Ameren Missouri TRM with savings values based on actual PY2 EMV Reports.

The measures in Tables 3.2.1 to 3.2.4 are:

- CFL PRE-EISA 13 Watt
- CFL - Fixture 391 Watt

[22] Appendix A, Ameren Missouri Technical Resource Manual, 2012 Energy Efficiency Filing, p. 2.

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- CFL PRE-EISA for Multifamily 13.5 Watt
- Freezer - Recycling
- Refrigerator - Recycling
- Energy Star Refrigerator
- Energy Star Freezer
- Electric Water Heater Wrap Multi Family
- Electric Water Heater Pipe Wrap Multi Family
- Low Flow Showerhead Multi Family
- Low Flow Faucet Aerator Multi Family
- Commercial Lighting 4-Lamp T5 Fluorescent Lighting Fixture Replacing 400 watt Metal Halide
- Commercial Lighting 6-Lamp T5 Fluorescent Lighting Fixture Replacing 400 watt Metal Halide
- Commercial Lighting 8-Lamp T8 Fluorescent Lighting Fixture Replacing 400 watt HID
- Commercial LED Exit Signs Replacing Incandescent Exit Sign
- GU-24 pin-based CFL
- Interior CF 1 L 26W Quad
- Interior CF 1 L 32W Triple
- New pin-based CFL Fixture (>45W)
- Passive Infrared or Ultrasonic
- Dual Technology Sensors
- Interior Wall Sensors
- Anti-Sweat Heat Controls
- Strip Curtains for Walk-in Coolers
- Beverage Vending Machine Controls
- Energy Star Vending Machine
- Lighted Snack Dispensing Vending Machine

The following tables present the final results of our analysis of energy savings values in the Ameren Missouri TRM.

- **Table 3.2.1:** Non-weather sensitive energy savings values in the Ameren Missouri TRM that fall within a range of energy savings values from other TRMs.
- **Table 3.2.2:** Energy savings values in the Ameren Missouri TRM that fall outside of the a range of energy savings values from other TRMs
- **Table 3.2.3:** Comparison of energy savings values in the Ameren Missouri TRM to other TRMs, where only one comparative energy savings value could be found.
- **Table 3.2.4:** Measures from the Ameren Missouri TRM for which no comparative values could be found in other TRMs

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Table 3.2.1
Summary of TRM Measure Savings Comparisons
Measures That Fall Within Range

Ameren Missouri TRM				Other TRMS - Savings Estimates						
Measure Type	Measure Name	Annual kWh Savings	Savings Source	Low	Average	High	Does Ameren Estimate Fall in Range?	Percent Difference of Ameren Savings from Other TRMs Average	Is Ameren Savings within +/- 10% of Other TRMS Average?	Comparison TRMs
Res Lighting	CFL POST-EISA 13 Watt	31.5	MML (1)	26.0	30.5	38.1	Yes	3%	Yes	OH, PA, Mid-Atlantic
Res Lighting	CFL POST-EISA 18 Watt	37.4	MML	27.2	36.8	52.7	Yes	2%	Yes	OH, PA, VT, Mid-Atlantic
Res Lighting	CFL- Torchiere Floor Lamps 55 Watt	164.0	MML	105.2	158.2	292.7	Yes	4%	Yes	MA, OH, PA, VT,
Res Lighting	LED Downlight E26 Light Bulb 10.5 Watt	54.5	Ameren TRM Formula	48.0	59.3	74.3	Yes	-8%	Yes	MA, VT, Mid-Atlantic
Res Appliances	Dehumidifier - Recycling	139.0	MML	66.0	114.9	182.8	Yes	21%	No	MA, NY, VT
Res Appliances	Room AC - Recycling	113.0	MML	16.6	118.7	256.0	Yes	-5%	Yes	MA, OH, NY, PA, VT, Mid-Atlantic
Res Appliances	Smart Strip Plug Outlet	184.0	MML	58.7	95.4	184.0	Yes	93%	No	MA, OH, PA, VT, Mid-Atlantic
Res Appliances	Variable Frequency Drive on Swimming Pool Pump	1,543.0	MML	400.0	960.0	1,676.0	Yes	61%	No	MA, OH, PA, Mid-Atlantic
Res Water Heating	Heat Pump Water Heater COP > 2.0	1,802.0	MML	1,162.0	1,457.7	1,914.0	Yes	24%	No	MA, OH, PA
Res Water Heating	Electric Water Heater Wrap Single Family	180.0	MML	79.0	142.4	200.0	Yes	26%	No	OH, NY, PA, VT, Mid-Atlantic
Res Water Heating	Water Heater Thermostat Set-Back 120 Degrees	163.0	MML	146.0	217.0	288.0	Yes	-25%	No	MA, VT
Res Water Heating	Electric Water Heater Pipe Wrap Single Family	257.0	MML	33.0	166.7	266.9	Yes	54%	No	OH, TX, VT, Mid-Atlantic
Res Water Heating	Low Flow Showerhead Single Family	361.0	MML	168.0	290.9	461.0	Yes	24%	No	OH, PA, TX, VT, Mid-Atlantic
Res Water Heating	Low Flow Faucet Aerator Single Family	57.0	MML	24.5	57.9	139.8	Yes	-2%	Yes	OH, PA, TX, VT, Mid-Atlantic
Com Lighting	Commercial Lighting 3-Lamp T5 Fluorescent Lighting Fixture Replacing 250 watt HID	449.0	MML	212.2	425.1	507.7	Yes	6%	Yes	MA, ME, OH, PA, Mid-Atlantic
Com Lighting	Commercial Lighting Double 6-Lamp T5 Fluorescent Lighting Fixture Replacing 1000 watt HID	1,456.0	MML	837.4	1,623.1	2,545.9	Yes	-10%	No	MA, ME, OH, NY, PA, Mid-Atlantic
Com Lighting	Commercial Lighting 4-Lamp TB Fluorescent Lighting Fixture Replacing 250 watt HID	616.0	MML	337.0	585.8	724.0	Yes	5%	Yes	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Lighting	Commercial Lighting 6-Lamp TB Fluorescent Lighting Fixture Replacing 400 watt HID	961.0	MML	578.2	950.0	1,161.4	Yes	1%	Yes	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Lighting	Commercial Lighting Double 8-Lamp T8 Fluorescent Lighting Fixture Replacing 1,000 watt HID	2,005.0	MML	1,611.6	2,108.0	2,423.4	Yes	-5%	Yes	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Lighting	Commercial Pulse Start Metal Halide	1,090.0	MML	1,089.9	1,173.5	1,220.7	Yes	-7%	Yes	MA, NY, PA, Mid-Atlantic

(1) Morgan Measure Libraries

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Table 3.2.1 (Continued)
Summary of TRM Measure Savings Comparisons
Measures That Fall Within Range

Ameren Missouri TRM				Other TRMS - Savings Estimates						
Measure Type	Measure Name	Annual kWh Savings	Savings Source	Low	Average	High	Does Ameren Estimate Fall in Range?	Percent Difference of Ameren Savings from Other TRMs Average	Is Ameren Savings within +/- 10% of Other TRMS Average?	Comparison TRMs
Com Lighting	Commercial Ceramic Metal Halide (20- 100 watt)	445.0	MML (1)	148.0	398.8	503.2	Yes	12%	No	MA, OH, NY, PA, Mid-Atlantic
Com Lighting	Commercial LED/Induction Garage Light Replacing HID Exterior Light	1,614.0	MML	1,594.3	1,727.2	1,801.6	Yes	-7%	Yes	MA, NY, PA, Mid-Atlantic
Com Lighting	Compact fluorescent lamp >= 30 W and <= 115	497.0	MML	496.8	531.9	561.4	Yes	-7%	Yes	MA, NY, PA, VT, Mid-Atlantic
Com Lighting	Compact fluorescent lamps with reflectors	202.0	MML	144.6	202.3	228.7	Yes	0%	Yes	MA, ME, NY, PA, VT, Mid-Atlantic
Com Lighting	LED lamp	177.0	MML	176.6	189.1	199.6	Yes	-6%	Yes	MA, NY, PA, VT, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Freezers 30 to 50 ft3	3,869.0	MML	3,869.0	3,869.0	3,869.0	Yes	0%	Yes	OH, NY, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Refrigerators less than 15 ft3	722.0	MML	720.1	720.8	722.0	Yes	0%	Yes	OH, NY, VT
Com Refrig	Energy Star Commercial Solid Door Freezers 15 to 30 ft3	869.0	MML	563.0	747.6	869.0	Yes	16%	No	ME, OH, NY, VT, Mid-Atlantic
Com Refrig	Energy Star Commercial Solid Door Freezers more than 50 ft3	3,757.0	MML	2,608.7	2,999.5	4,171.0	Yes	25%	No	OH, NY, VT, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 3 HP	3,246.2	MML	2,636.1	4,388.5	7,014.2	Yes	-26%	No	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 5 HP	5,356.7	MML	4,393.5	7,287.8	11,573.8	Yes	-26%	No	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 7.5 HP	8,116.2	MML	6,590.2	10,971.2	17,535.4	Yes	-26%	No	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 10 HP	10,713.4	MML	8,787.0	14,575.6	23,147.6	Yes	-26%	No	MA, ME, OH, NY, PA, VT, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 15 HP	16,232.3	MML	13,180.4	21,234.4	35,070.9	Yes	-24%	No	MA, ME, OH, NY, PA, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 20 HP	21,643.1	MML	17,573.9	28,312.5	46,761.1	Yes	-24%	No	MA, ME, OH, NY, PA, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 25 HP	27,053.9	MML	21,967.4	33,738.7	58,451.4	Yes	-20%	No	MA, OH, NY, PA, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 30 HP	32,464.6	MML	26,360.9	40,486.5	70,141.7	Yes	-20%	No	MA, OH, NY, PA, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 40 HP	43,286.2	MML	35,147.9	53,982.0	93,522.3	Yes	-20%	No	MA, OH, NY, PA, Mid-Atlantic
Com Motors	VFDs for Process Pumping - 50 HP	54,108.4	MML	43,934.8	67,477.5	116,902.9	Yes	-20%	No	MA, OH, NY, PA, Mid-Atlantic

(1) Morgan Measure Libraries

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Table 3.2.2
Summary of TRM Measure Savings Comparisons
Measures That Fall Outside of Range

Ameren Missouri TRM				Other TRMS - Savings Estimates						
Measure Type	Measure Name	Annual kWh Savings	Savings Source	Low	Average	High	Does Ameren Estimate Fall in Range?	Percent Difference of Ameren Savings from Other TRMs Average	Is Ameren Savings within +/- 10% of Other TRMS Average?	Comparison TRMs
Res Lighting	CFL POST-EISA 23 Watt	51.2	MML (1)	42.7	44.7	46.2	No	15%	No	OH, PA, Mid-Atlantic
Res Lighting	CFL - High Watt 65 Watt	113.0	MML	123.8	159.9	192.1	No	-29%	No	MA, OH, NY, PA, VT,
Res Lighting	CFL - Specialtly 26.5 Watt	44.1	MML	48.3	59.2	75.8	No	-25%	No	MA, OH, NY, PA, TX, VT, Mid-Atlantic
Res Lighting	CFL POST -EISA for Multifamily 13 Watt	31.5	MML	24.0	25.8	27.6	No	22%	No	OH, PA
Res Appliances	Two Speed High Efficiency Pool Pump	1,081.0	MML	400.0	491.0	594.0	No	120%	No	MA, OH, PA, Mid-Atlantic
Res Water Heating	Efficient Electric Tank Storage Water Heater 0.93 EF	157.0	MML	77.0	120.3	150.0	No	30%	No	MA, TX, VT
Com Lighting	Compact fluorescent lamp less than 30W	202.0	MML	202.4	216.7	228.7	No	-7%	Yes	MA, NY, PA, VT, Mid-Atlantic
Com Lighting	Occupancy Sensors under 500 W	397.0	MML	428.7	454.7	480.7	No	-13%	No	OH, PA
Com Cooking	Energy Star Steam Cooker - 3 Pan	11,188.0	MML	2,813.0	4,143.4	5,473.8	No	170%	No	OH, PA
Com Cooking	Energy Star Steam Cooker - 4 Pan	12,159.0	MML	3,902.0	4,997.9	6,093.9	No	143%	No	OH, PA
Com Cooking	Energy Star Steam Cooker - 5 Pan	13,139.0	MML	5,134.0	5,968.2	6,802.5	No	120%	No	OH, PA
Com Cooking	Energy Star Steam Cooker - 6 Pan	15,170.0	MML	6,311.0	6,911.0	7,511.1	No	120%	No	OH, PA
Com Refrig	Energy Star Commercial Solid Door Freezers less than 15 ft3	595.0	MML	458.1	478.1	538.0	No	24%	No	OH, NY, VT, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Freezers 15 to 30 ft3	2,004.0	MML	2,001.1	2,001.4	2,002.0	No	0%	Yes	OH, NY, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Freezers less than 15 ft3	722.0	MML	1,562.0	1,568.4	1,581.2	No	-54%	No	OH, NY, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Freezers more than 50 ft3	7,118.0	MML	5,694.0	5,694.0	5,694.0	No	25%	No	OH, NY, Mid-Atlantic
Com Refrig	Energy Star Commercial Glass Door Refrigerators 15 to 30 ft3	1,434.0	MML	671.6	677.7	690.0	No	112%	No	OH, NY, VT
Com Refrig	Energy Star Commercial Solid Door Freezers 30 to 50 ft3	1,728.0	MML	1,728.3	1,838.5	2,169.0	No	-6%	Yes	OH, NY, VT, Mid-Atlantic
Com Motors	VFDs for Air Compressors	5.8	MML	404.5	602.3	800.2	No	-99%	No	OH, PA

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Table 3.2.3
Summary of TRM Measure Savings Comparisons
Only One Other TRM Comparison

Ameren Missouri TRM				Other TRMS - Savings Estimates			
Measure Type	Measure Name	Annual kWh Savings	Savings Source	Average	Percent Difference of Ameren Savings from Other TRM	Is Ameren Savings within +/- 10% of Other TRM?	Comparison TRM
Res Lighting	LED Dimmable Light Bulb 12 Watt	48.0	Ameren TRM Formula	54.2	-11%	No	MA
Res Lighting	LED Flood PAR30 Bulb POST-EISA 15 Watt	35.0	Ameren TRM Formula	51.1	-32%	No	MA
Res Lighting	LED Flood PAR38 Bulb POST - EISA 18 Watt	32.0	Ameren TRM Formula	48.0	-33%	No	MA
Res Lighting	LED Globe G25 Bulb 8 Watt	32.0	Ameren TRM Formula	58.3	-45%	No	MA
Res Lighting	Metal Halide Outdoor Lighting 35 Watt	189.8	MML (1)	156.0	22%	No	MA
Res Lighting	Occupancy Sensor	217.0	MML	99.0	119%	No	MA
Com Hot Water	Commercial Heat Pump Water Heater - 10K-50K BTU/h >= 3.0 COP	21,156.0	MML	21,449.8	-1%	Yes	NY
Com Hot Water	Commercial Heat Pump Water Heater - 50k-100k BTU/h >= 3.0 COP	52,890.0	MML	53,624.6	-1%	Yes	NY
Com Hot Water	Commercial Heat Pump Water Heater - 300k-500k BTU/h >= 3.0 COP	282,081.0	MML	285,998.8	-1%	Yes	NY
Com Hot Water	Commercial Heat Pump Water Heater > 500k BTU/h >= 3.0 COP	423,122.0	MML	428,998.7	-1%	Yes	NY
Com Hot Water	Pre-Rinse Spray Valves <= 0.64 gpm	5,626.0	MML	650.2	765%	No	NY
Com Hot Water	Low Flow Faucet Aerators <= 1.5 gpm	174.0	MML	108.5	60%	No	NY
Com Misc	Tractor Heater Timers	576.0	Focus on Energy Evaluation Business Programs: Deemed Savings Manual v1.0	664.0	-13%	No	NY
Res Appliances	Single Speed High Efficiency Pool Pump	694.0	MML	409.0	70%	No	OH
Com Cooking	Energy Star Hot Food Holding Cabinets - Full Size > 15 ft3	5,278.0	MML	5,256.0	0%	Yes	OH
Com Cooking	Energy Star Hot Food Holding Cabinets - Three-Quarter Size 10- 15 ft3	2,832.0	MML	2,847.0	-1%	Yes	OH
Com Cooking	Energy Star Hot Food Holding Cabinets - Half Size < 10 ft3	1,788.0	MML	1,862.0	-4%	Yes	OH

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Table 3.2.4
Summary of TRM Measure Savings Comparisons
No Other TRM Comparisons Found

Ameren Missouri TRM			
Measure Type	Measure Name	Annual kWh Savings	Savings Source
Res Water Heating	Geothermal Heat Pump Desuperheater	1,540.0	MML (1)
Com Lighting	Commercial LED Case Lighting	429.0	MML
Com Lighting	Occupancy Sensors over 500 W	994.0	MML
Com Lighting	Central Lighting Control	11,500.0	MML
Com Lighting	Sw itching Controls for Multilevel lighting	8,000.0	MML
Com Lighting	Daylight Sensor controls	14,800.0	MML
Com Lighting	Retro-Commissioning Lighting	5,311.4	MML
Com Refrig	Energy Star Ice Machine > 1000 lbs/24 hours	6,048.0	MML
Com Hot Water	Commercial Heat Pump Water Heater - 100k-300k BTU/h >= 3.0 COP	141,041.0	MML
Com Misc	Window Repalcement	30,575.0	MML
Com Opt	Optimized Process Cooling	16,325.0	MML
Com Opt	Optimized Process Heating	7,053.0	MML
Com Opt	Compressed Air Optimization	200.0	MML
Res Lighting	CFL - Reflector 20 Watt	44.1	MML
Res Lighting	HID Outdoor Bulb 505 Watt	603.0	MML
Res Lighting	Airtight Can Bulb for Multifamily N/A Watt	85.0	MML
Com Refrig	Energy Star Ice Machine < 500 lbs/24 hours	1,652.0	MML
Com Refrig	Energy Star Ice Machine 500 - 1000 lbs/24 hours	2,695.0	MML
Com Motors	Commercial Pumps for Process - 1.5 HP 5.66% Improvement	1,991.0	MML
Com Motors	Commercial Pumps for Process - 2 HP 7.48% Improvement	513.0	MML
Com Motors	Commercial Pumps for Process - 3 HP 7.19% Improvement	573.0	MML
Com Motors	Commercial Pumps for Process - 5 HP 2.86% Improvement	664.0	MML
Com Motors	Commercial Pumps for Process - 5 HP 21.3% Improvement	9,232.0	MML
Com Motors	Commercial Pumps for Process - 5 HP 12.9% Improvement	4,405.0	MML
Com Motors	Commercial Pumps for Process - 5 HP 13.75% Improvement	1,569.0	MML
Com Motors	Commercial Pumps for Process - 5 HP 24.54% Improvement	4,254.0	MML
Com Motors	Commercial Pumps for Process - 7.5 HP 7.48% Improvement	1,840.0	MML
Com Motors	Commercial Pumps for Process - 7.5 HP 6.05% Improvement	1,720.0	MML
Com Motors	Commercial Pumps for Process - 10 HP 2.96% Improvement	1,026.0	MML
Com Motors	Commercial Pumps for Process - 10 HP 4.6% Improvement	1,629.0	MML
Com Motors	Commercial Pumps for Process - 10 HP 12.25% Improvement	4,043.0	MML
Com Motors	Commercial Pumps for Process - 15 HP 16.09% Improvement	7,332.0	MML
Com Motors	Commercial Pumps for Process - 20 HP 2.45% Improvement	1,267.0	MML
Com Motors	Commercial Pumps for Process - 20 HP 9.24% Improvement	5,340.0	MML
Com Motors	Commercial Pumps for Process - 20 HP 4% Improvement	3,409.0	MML

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3.3 Recommendations

GDS recommends that the Ameren Missouri TRM be accepted with the following revisions:

(1) All equations identified as incorrect should be revised.

(2) All key assumptions that are identified as missing, incorrectly stated, not defined or not sourced should be added or corrected.

(3) Equations identified as non-calculative should be revised such that they will actually calculate base and efficient use based on key inputs such as equipment wattage, horsepower, operating hours, and efficiency ratings.

(4) Interactive factors, in-service rates and in situ adjustment factors should be added to equations where they have been identified as missing. It is important to identify these factors in all energy savings equations, whenever it is appropriate, even if the factor values are set to 1.0.

(5) Alternative equations suggested by GDS to improve the precision of the energy savings estimates should be either adopted by Ameren Missouri or an explanation should be provided explaining why the current equation is preferred.

(6) Other issues with equations that have been identified by GDS should be reviewed by Ameren Missouri and any necessary TRM changes should be made or a response should be provided.

(7) In the absence of new evaluation data addressing measures with questionable savings estimates, additional research should be conducted on those measures in Table 3.2.2 above that have been identified as having savings estimates that are outside the range of estimates from other TRMs and also differ by more than ± 10% from the average "other TRMs" energy savings. The purpose of this additional research would be to determine if the differences identified by GDS are valid and if not, to make any necessary changes to energy savings values.

(8) In the absence of additional evaluation data addressing measures for which only one or no comparative values from other TRMs could be found, Ameren Missouri should conduct additional research to assess the reasonableness of energy savings estimates for such measures.