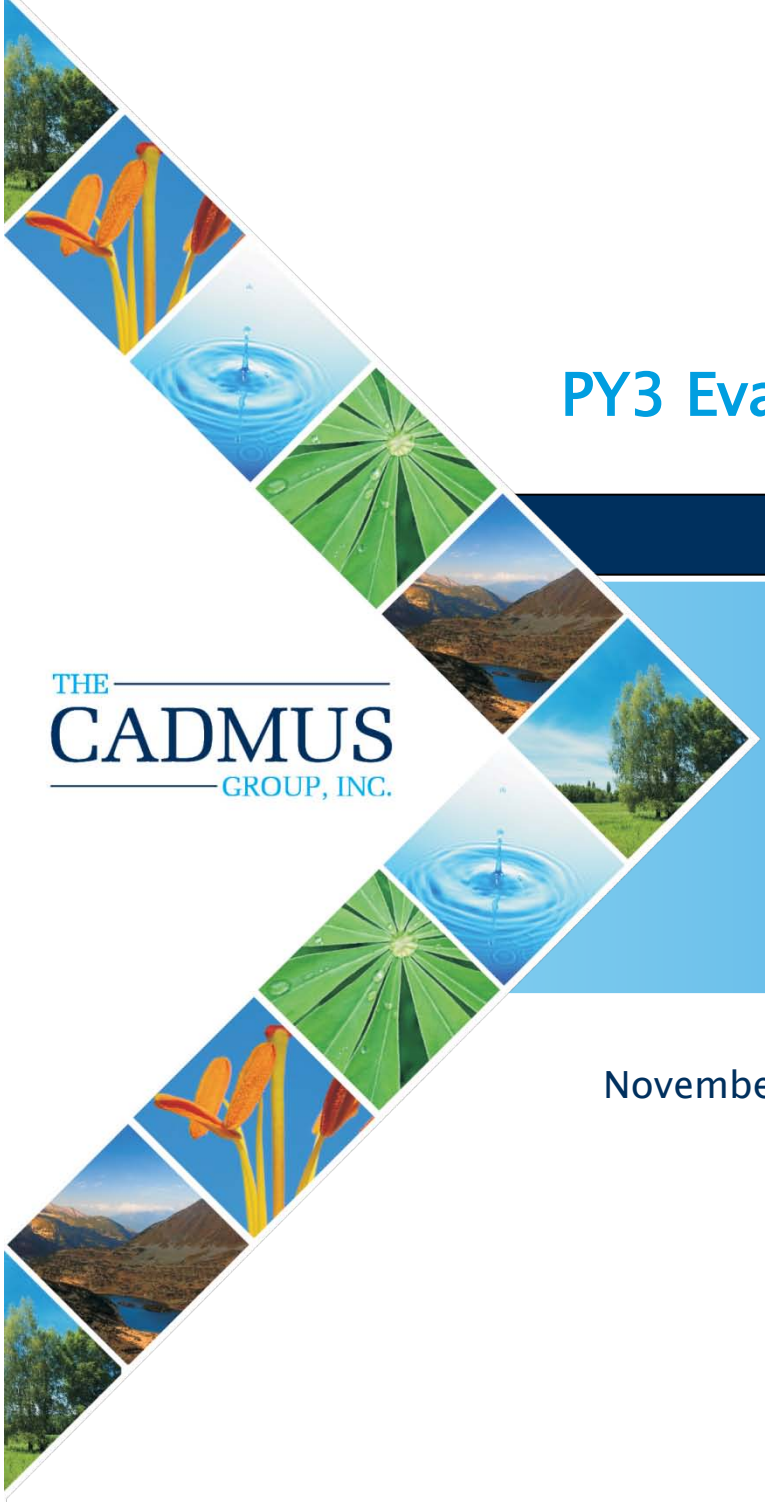

PY3 Evaluation

Multifamily Program Evaluation

November 2011

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Executive Summary

The Ameren Illinois Multifamily Program is offered to privately owned, market-rate, multifamily buildings with three or more dwelling units in Ameren Illinois' service territory. The program has two components:

- The Common-Area Lighting Program provides incentives for installation of energy-efficient lighting including lighting fixture upgrades and retrofits, compact fluorescent bulbs (CFLs) to replace incandescent bulbs, occupancy sensor installation, and inefficient exit sign lighting replacement/retrofit.
- The In-Unit Energy Efficiency Program offers free CFLs and water conservation measures (efficient showerheads, faucet aerators, and pipe insulation) along with an informational brochure for residents on measures installed.

The program launched in November 2008. This evaluation examines the program's performance in PY3, which ran from June 2010 through May 2011. Conservation Services Group (CSG) implements the program.

Both gas- and electricity-saving measures are included in the Program; however, this report contains only results of kWh and kW savings. Therm savings will be presented in a separate gas results summary memo.

PY3 energy savings were estimated by reviewing and analyzing the tracking database and applying savings estimates based on past PY1 and PY2 evaluation activities. Savings estimate sources are displayed in Table ES-1.

Table ES-1. Savings Estimate Sources

Savings Estimate	Source
Faucet aerator per unit energy savings	Memo: Domestic Hot Water Savings Revisions, November, 22, 2011 (Appendix A)
Showerhead per unit energy savings	Memo: Domestic Hot Water Savings Revisions, November, 22, 2011 (Appendix A)
Pipe insulation per unit energy savings	Domestic Hot Water Savings Analysis Addendum to PY2 Multifamily and Home Energy Performance Reports, Memo to Karen Kansfield, from Robert Huang, Cadmus, February 9, 2011.(Appendix B)
Multifamily Common-Area Lighting savings	Multifamily Properties Program Evaluation – PY2, dated December 2010, page 13 describes the engineering formula used. Inputs from PY3 tracking database were applied to calculate savings.
Multifamily In-Unit Lighting savings	Lighting per unit savings were deemed by the Illinois Commerce Commission in the Order for docket 07-0539.
Net-to-Gross Ratio (NTG)	Used results from PY2 report (Multifamily Properties Program Evaluation – PY2 dated December, 2010, pages 19-21) determined through a participant survey of 35 building owners and managers. .

Table ES-2 summarizes participation and gross savings for the various program components.

Table ES-2. Program Gross Savings

Product	Total Program Measures Installed	Realized Gross Energy Savings (MWh)	Realized Gross Demand Savings (kW)
Multi-Family In-Unit	56,599	3,752	343.8
Multi-Family Common Area	1,969	387	61.9
Total - PY3	58,568	4,139	406

Table ES-3 summarizes the programs *ex ante* gross savings, realized gross savings, and the NTG ratio for in-unit versus common area measures. *Ex ante* savings estimates were previously reviewed by Cadmus and assumed by Ameren Illinois in the database. Therefore *ex ante* and realized savings were the same. For PY3 Cadmus did not perform any additional primary research to evaluate this program and therefore we apply the same NTG ratios for in-unit (1.0) and common area (0.8) measures as applied in PY2.

Table ES-3. *Ex Ante* Gross Savings, Realized Savings, and Net Savings

Measure	Ex Ante Gross Savings (MWh)	Realized Gross Savings (MWh)	NTGR	Net Energy Savings (MWh)	Net Demand Savings (kW)
In Unit Measures					
15 watt CFL	1,538	1,538	1.0	1,538	86
20 watt CFL	227	227	1.0	227	13
23 watt CFL	38	38	1.0	38	2
Faucet Aerator	479	479	1.0	479	60
Pipe Insulation	42	42	1.0	42	5
Showerhead 2.0 GPM	1,429	1,429	1.0	1,429	178
Common Area Measures					
4-foot T8 (32w lamps with electronic ballast and reflector)	87	87	0.8	70	11
4-foot T8 (32w lamps with electronic ballast)	97	97	0.8	77	12
Integral CFL (>13 watts screw-in)	141	141	0.8	113	18
LED Exit Sign (new fixture or LED retro-fit)	56	56	0.8	44	7
Modular CFL (<=18 watts, pin-based electronic ballast fixture)	2.1	2.1	0.8	1.6	0.3
Modular CFL (>18 watts, pin-based electronic ballast fixture)	0.0	0.0	0.8	0.0	0.0
Occupancy Sensor	4.4	4.4	0.8	3.5	0.6
Total	4,139	4,139	-	4,062	393

Cadmus reviewed the *ex ante* gross savings and verified that the proper deemed savings values were used for in-unit measures and that the energy savings algorithm was correct for common-area measures. The realization rate for all measures was 100 percent, and a total of 4,062 MWh was calculated.

A total of 166 properties participated in PY3, a 24 percent increase from the previous year, mostly driven by installation of in-unit measures. Ninety three percent of participating properties installed in-unit measures only (155 out of 166 participants).

Table ES-4. Participating Buildings

Multifamily Program	Number of PY1 Sites	Number of PY2 Sites	Number of PY3 Sites
Common Area (Lighting Only)	3	2	0
In-Unit Only*	59	122	155
Both Common Area and In-Unit*	7	10	11
Total Number of Facilities	69	134	166

*Includes both gas-heated and electrically heated properties

Program trends show that, even though overall participation is increasing, common-area installations are not as popular as in-unit installations, as shown in Figure ES-1.

Figure ES-1. Gross Program Energy Savings by Measure Location and Program Year

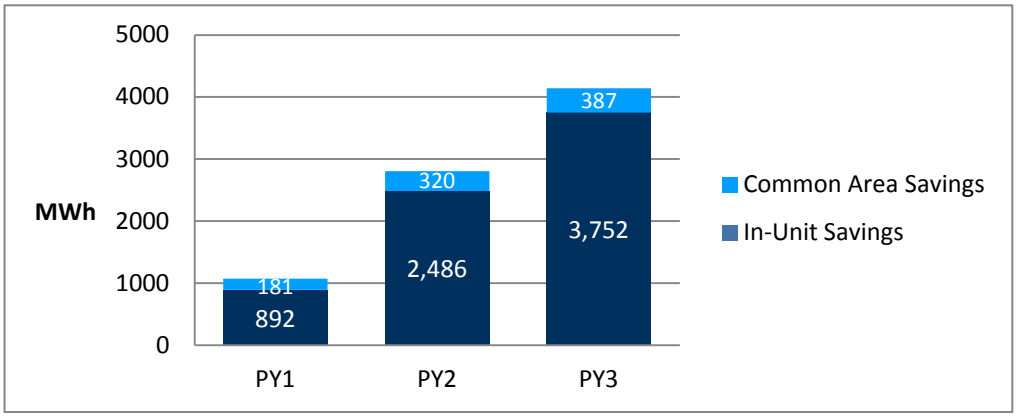

Table ES-5 summarizes and compares the PY3 results to PY1 and PY2.

Table ES-5. PY3 Multifamily Program Gross and Net Results

Program Year	Gross Energy Savings MWh	Gross Demand Savings kW	Net Energy Savings MWh	Net Demand Savings kW
PY3	4,139	406	4,062	393.3
PY2	2,805	272	2,741	262
PY1	1,073	107	816	82
Cumulative to Date	8,017	785	7,619	737

Based on the stakeholder interviews Ameren Illinois pursued recommendations made in the PY2 report. They are considering adding a custom measure option to the program in the future. Cadmus agrees this approach could help improve participation in the common area portion of the program.

Introduction

Program Description

The Multifamily Program is offered to privately owned, market-rate multifamily buildings with three or more dwelling units in Ameren Illinois' service territory. The program has two components:

- The Common-Area Lighting Program offers incentives for installation of energy-efficient lighting, including the following:
  - Lighting fixture upgrades and retrofits
  - Compact fluorescent bulbs (CFLs) to replace incandescent bulbs
  - Occupancy sensor installation
  - Inefficient exit sign lighting replacement/retrofit
  - Programmable thermostats
  - Shell measures
- The In-Unit Energy Efficiency Program offers free CFLs and water conservation measures (efficient showerheads, faucet aerators, and pipe insulation) along with an informational brochure for residents on measures installed.

The program launched in November 2008. This evaluation examines the program's performance in Program Year 3 (PY3), which ran from June 2010 through May 2011. Conservation Services Group (CSG) implements the program for Ameren Illinois.

Programmable thermostats and shell measures were new additions to PY3 offerings for gas-heating buildings only; however no participants applied for these incentives.

The following rebate amounts are offered to customers installing measures for the Common-Area Lighting Program, as summarized in Table 1.

Table 1. Rebate Amounts

Common Area Lighting	Rebate
4' T8 (32 watt lamps with electronic ballast and reflector)	$9
4' T8 (32 watt lamps with electronic ballast)	$7
Integral CFL (>13 watts screw-in)	$1.50
LED exit sign (new fixture or LED retrofit)	$22
Modular CFL (<=18 watts pin-based electronic ballast fixture)	$23
Occupancy sensor	$25

Evaluation Methods

Cadmus' PY3 evaluation consisted of a summary of the tracking database, verification of savings in the tracking database and a stakeholder interview.

Tracking Database Analysis

The PY3 evaluation consisted of reviewing and analyzing the program's tracking database and applying savings estimates based on past PY1 and PY2 evaluation activities. Sources of savings estimates are displayed in Table 2.

Table 2. Savings Estimate Sources

Savings Estimate	Source
Faucet aerator per unit energy savings	Memo: Domestic Hot Water Savings Revisions, November, 22, 2011 (Appendix A)
Showerhead per unit energy savings	Memo: Domestic Hot Water Savings Revisions, November, 22, 2011 (Appendix A)
Pipe insulation per unit energy savings	Domestic Hot Water Savings Analysis Addendum to PY2 Multifamily and Home Energy Performance Reports, Memo to Karen Kansfield, from Robert Huang, Cadmus, February 9, 2011.(Appendix B)
Multifamily Common-Area Lighting savings	Multifamily Properties Program Evaluation – PY2, dated December 2010, page 13 describes the method. Inputs from PY3 tracking database were used to calculate savings.
Multifamily In-Unit Lighting savings	Lighting per unit savings were deemed by the Illinois Commerce Commission in the Order for docket 07-0539.
Net-to-Gross Ratio (NTG)	Multifamily Properties Program Evaluation – PY2 dated December, 2010, pages 19-21.

Cadmus received copies of the program database CSG maintains. The database extract was in Microsoft Excel format and included records of all projects completed during PY3. Common-area and in-unit measures were listed on separate tabs. Each record represented a bundle of measures installed on a certain date at a certain property. The database did not contain information at the unit level. If additional measures were installed at a later date, those installations were recorded in a separate entry.

Cadmus reviewed the program database and forms during the PY2 evaluation, and performed site visits to compare actual installations to application forms. For PY3, Cadmus checked the database for errors and data quality. Energy savings for each measure were recalculated using either the deemed savings value for in-unit measures or the annual kWh savings algorithm for common area measures. Cadmus confirmed that the reviewed measure savings matched the PY3 database.

Stakeholder Interview

A stakeholder interview was conducted with both the Ameren Illinois program manager and CSG's program. Topics covered included any program design changes that were made for PY3, challenges during the implementation, and how the recommendations from the PY2 evaluation were addressed in PY3.

Data Sources

The following data sources informed the PY3 evaluation:

- Final PY3 program database (provided by CSG)
- Information gathered through program manager interview
- PY2 reports and analysis
- DHW Savings analysis summarized in Appendices A and B

Program Results

Summary of Program Participation

Program participation increased during PY3, as shown in Table 3. A total of 166 properties participated in PY3, a 24 percent increase over the previous year. Ninety-three percent of participating properties installed in-unit measures only (155 out of 166 participants). This may have been caused by the requirement that participants pay a percentage of the cost for common area, and not for in-unit measures.

Table 3. Participating Buildings

Multifamily Program	Number of PY1 Sites	Number of PY2 Sites	Number of PY3 Sites	% Change from PY2
Common-Area Lighting Only	3	2	0	-100%
In-Unit Only*	59	122	155	+27%
Both Common-Area and In-Unit*	7	10	11	+10%
Total Number of Facilities	69	134	166	+24%

*Includes both gas-heated and electrically heated properties

Determination of Gross Savings

Cadmus reviewed the common area savings tracked in the database by comparing the database values to savings Cadmus had calculated. Cadmus calculated common-area lighting savings for each measure bundle using the following formula:

$$\textit{Annual kWh Savings} = (kW_{existing} - kW_{new}) \times \textit{Annual Operating Hours} \times \textit{Quantity Installed}$$

This formula applies to all common area measures except for occupancy sensors, which are estimated to save 210 kWh per site, as reviewed by Cadmus in 2010. The database values were consistent with the Cadmus savings calculations.

For in-unit measures, which were reviewed during the PY1 evaluation, Cadmus used the same values as those used in PY1 and listed in Table 4. Lighting savings were determined based on the deemed values from the final Order in ICC Docket # 07-0539, lighting savings and match the program database. We calculated domestic hot water measures savings after performing secondary research on inputs and values from other areas. These savings estimates are new for the PY3 evaluation.[1]

[1] Domestic Hot Water Savings Analysis Addendum to PY2 Multifamily and Home Energy Performance Reports Memo, from Jane Colby and Dave Korn dated September 12, 2011.

Table 4. In-Unit Measures Gross Savings

Measure	Per-unit kWh Savings
15 watt CFL	38.40
20 watt CFL	47.00
23 watt CFL	65.80
Faucet Aerator	71.1
Pipe Insulation	51.40
Showerhead 2.0 gpm	398.4

Cadmus calculated demand savings by multiplying energy savings by the appropriate end-use coincidence factor used in the PY2 report. The coincidence factors were calculated directly from hourly end-use load shapes. Hourly end-use load shapes were developed from engineering models for the Midwestern region of the United States, which were then calibrated to long-term weather conditions in Ameren Illinois' service area.

Total gross savings for PY3 are 4,139MWh, with 9 percent attributed to common-area lighting measures and 91 percent to in-unit measures. In-unit measure savings increased by 51 percent in PY3, while common area savings increased by 21 percent over PY2, as shown in Figure 1.

Figure 1. Gross Program Savings by Measure Location

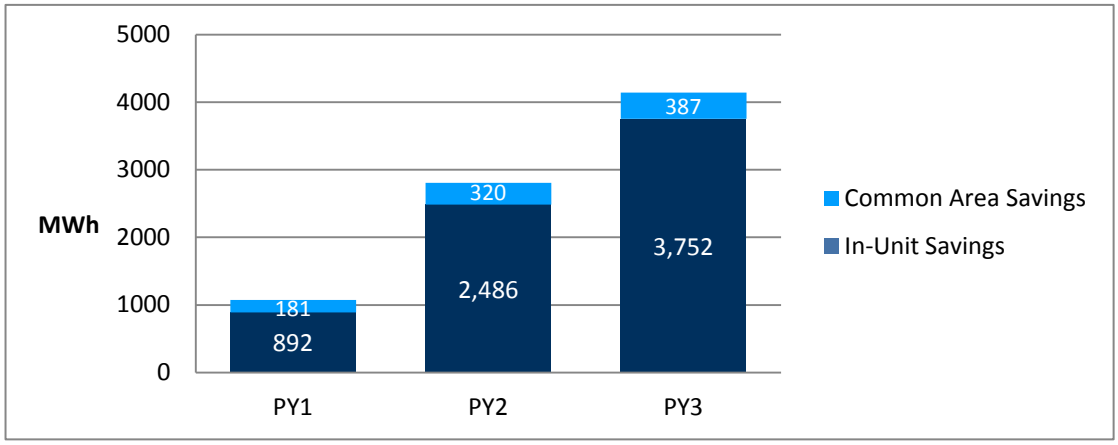

Table 5 details common-area measure installations, including the measure type, quantity installed, and gross kWh and kW savings.

Table 5. Common-Area Measure Distribution and Gross Savings

Measure	Quantity Installed	Gross kWh Savings	Gross kW Savings
4-foot T8 (32 watt lamps with electronic ballast and reflector)	232	87,250	14.0
4-foot T8 (32watt lamps with electronic ballast)	970	96,734	15.5
Integral CFL (>13 watts screw-in)	493	140,756	22.5
LED exit sign (new fixture or LED retrofit)	243	55,617	8.9
Modular CFL (<=18 watts, pin-based electronic ballast fixture)	10	2,059	0.3
Modular CFL (>18 watts, pin-based electronic ballast fixture)	0	0	0
Occupancy sensor	21	4,410	0.7
Total	1,969	386,825	61.9

The measure most often installed in common areas was the 4-foot T8 fixture with electronic ballast. The majority of the common-area lighting savings, however, came from the integral CFL installations. The average hours of operation for CFLs were typically three hours greater than the 4-foot T8 fixtures. In addition, the change in wattage for common area retrofits was on average 40 watts less for 4-foot T8 fixtures than for the CFLs.

Table 6 shows the measure types, quantity installed, and gross kWh and kW savings for in-unit measure installations. Note that only electric water heating measures were counted.

Table 6. In-Unit Measure Distribution and Gross Savings

Measure	Quantity Installed	Gross kWh Savings	Gross kW Savings
15 watt CFL	40,052	1,537,997	86
20 watt CFL	4,832	227,104	13
23 watt CFL	577	37,967	2
Faucet Aerator	6,735	478,859	60
Pipe Insulation	817	41,667	5
Showerhead 2.0 GPM	3,586	1,428,662	178
Total	56,599	3,752,255	343.8

As shown, the 15-watt CFL was the measure most often installed in units, and it contributed the most to savings.

Determination of Net Savings

Because the in-unit measures were provided free-of-charge to building owners and managers, we applied a NTG ratio of 1.0 those installations[2]. For common-area measures, Cadmus applied the NTG ratio of 0.8 estimated through the surveys of building owners and managers from PY2. Results are shown in Table 7.

[2] Since the recipient was obviously not shopping for light bulbs, the typical free-ridership question of would they purchase the bulbs even without the program does not apply.

Table 7. Gross and Net Energy and Demand Savings by Measure

Measure	Ex Ante Gross Savings (MWh)	Realized Gross Savings (MWh)	NTGR	Net Energy Savings (MWh)	Net Demand Savings (kW)
In Unit Measures					
15 watt CFL	1,538	1,538	1.0	1,538	86
20 watt CFL	227	227	1.0	227	13
23 watt CFL	38	38	1.0	38	2
Faucet Aerator	479	479	1.0	479	60
Pipe Insulation	42	42	1.0	42	5
Showerhead 2.0 GPM	1,429	1,429	1.0	1,429	178
Common Area Measures					
4-foot T8 (32w lamps with electronic ballast and reflector)	87	87	0.8	70	11
4-foot T8 (32w lamps with electronic ballast)	97	97	0.8	77	12
Integral CFL (>13 watts screw-in)	141	141	0.8	113	18
LED Exit Sign (new fixture or LED retro-fit)	56	56	0.8	44	7
Modular CFL (<=18 watts, pin-based electronic ballast fixture)	2.1	2.1	0.8	1.6	0.3
Modular CFL (>18 watts, pin-based electronic ballast fixture)	0.0	0.0	0.8	0.0	0.0
Occupancy Sensor	4.4	4.4	0.8	3.5	0.6
Total	4,139	4,139	-	4,062	393

Over the past three years, multifamily program energy savings have increased considerably. Table 8 shows the program participation and net savings for each program year from 2008-2011.

Table 8. Multifamily Program Gross and Net Results PY1–PY3

Program Year	Gross MWh Savings	Gross kW Savings	Net MWh Savings	Net kW Savings
PY3	4,139	406	4,062	393
PY2	2,805	272	2,741	262
PY1	1,073	107	816	82
Cumulative Total	8,017	785	7,619	737

Program Stakeholder Interview

Cadmus interviewed program stakeholders representing both Ameren Illinois and CSG to determine the changes that were made from PY2 to PY3. In PY2, Cadmus made several process improvement recommendations, which included the following:

- Put more emphasis on marketing for common-area measures.
- Focus on defining the program so all stakeholders have the same understanding of how the program works and how to optimize eligibility.

- Change application, materials request, and post-installation forms to an electronic format.
- Update the Website address links for program information.
- Implement a naming convention for program participant files.
- Implement continuous quality control checks for the program documentation.

The stakeholder interviews revealed that most of these changes had been considered and implemented over the course of PY3. Cadmus determined that the recommendation for an electronic online application was not implemented due to concerns of a loss of data quality in the internal review processes for new applications. The interview also revealed that the overall paperwork processes had been reassessed following PY2 and updated for PY3 with a greater emphasis on quality assurance.

In looking at PY4, Ameren Illinois expressed interest in expanding the list of conservation measures available to its customers and in offering a "custom measure" rebate. The program will also be adding two energy advisors one day per week to assist the account managers with the direct-installations for the in-unit measures.

Appendix A: Domestic Hot Water Savings Revisions

Date: November 22, 2011
To: Karen Kansfield, Ameren Illinois
From: Jane Colby and Dave Korn, The Cadmus Group Inc.
Re: Domestic Hot Water Savings Revisions

At Ameren Illinois' request, Cadmus reviewed our previous[3] engineering estimate of unit savings for two domestic hot water (DHW) measures for the Home Energy Performance and Multifamily programs--faucet aerators and showerheads. **The purpose of this memo is to describe how these revised results, shown in Table 1, were calculated.**

Table 1. Domestic Hot Water Unit Revisions Savings Summary

DHW Default Savings Estimates								
Type of Water Heater	Faucet Aerator				Low-Flow Showerheads			
	Single Family		Multifamily		Single Family		Multifamily	
	Savings	Per	Savings	Per	Savings	Per	Savings	Per
Electric (in kWh)	57	aerator	71.1	aerator	361	shower-head	398.4	shower-head
Gas (in therms)	2.6	aerator	3.2	aerator	16	shower-head	17.7	shower-head

Aerators

We calculated energy savings by assuming a decrease in flow rate through the aerators in kitchen and bathroom faucets. This decrease in flow led to energy savings calculated for electric and gas water heaters, shown in Equations 1 and 2 below, respectively:

Equation 1:

Annual Electric DHW Savings (in kWh) per Person for bathroom and kitchen aerators = $(8.33*1*TIME*(FR_b-FR_e)*(T_{in}-T_{out})*DAY_h/3{,}413)/EFF_{elec}$

Equation 2:

Annual Gas DHW Savings (in therms) per Person for bathroom and kitchen aerators = $(8.35*1*FR_b*TIME*(FR_b-FR_e)/FR_b)*(T_{in}-T_{out})*DAY_h/100{,}000)/EFF_{gas}$

Where the labeled variables are listed in Table 2 and the constants in the equations are:

- *8.35 lbs per gallon*
- *1 BTU/lb-degree F = amount of energy to raise 1 lb of water 1 degree F*
- *3,413 BTUs per kWh*
- *100,000 BTUs per therm*

[3] Memo from Jane Colby and Robert Huang to Karen Kansfield, dated February 9, 2011.

The inputs into Equations 1 and 2, as well as the results of the savings calculation, are shown in the Table 2. The key changes between previous evaluations and this evaluation is the assumption around whether flow rates are throttled. We previously assumed a baseline flow rate of 1.85 gpm and an aerator flow rate of 1.48 gpm. These flow rates are consistent with water consumption being throttled (i.e. the faucet not running full out). Cadmus reviewed DWH savings from other program estimates[4] and determined our previous estimate was significantly lower than the average. We then reviewed input assumptions and determined the most significant difference between our approach and others was that others do not assume throttled flow. The new flow rates, as shown in Table 2, are based flows measured at HEP audit sites during PY1 that have not been throttled. We then weighted the annual DHW savings per person by the ratio of kitchen to bathroom aerator PY1 installs. We multiplied the annual weighted DHW savings per person by the number of people living in the home and divided by the number of sinks per home to derive an annual per aerator savings for either single or multifamily homes in the Ameren Illinois service territory.

Table 2. Assumptions Used in Aerator Calculation

Estimate of Default Saving for Aerators				
Type of Water Heater	Electric		Gas	
Measure Name	Kitchen Aerator	Bathroom Aerator	Kitchen Aerator	Bathroom Aerator
Number Installed at Ameren Illinois [a]	5	38	59	680
Efficient Aerator Flow Rate (FRe)[b]	2.2	1.5	2.2	1.5
Baseline Aerator Flow Rate (FRb)[c]	2.75	2.25	2.75	2.25
Water Heater Recovery Efficiency (EFF)[d]	100%	100%	77%	77%
Tin (in °F)[e]	53.9	53.9	53.9	53.9
Tout (in °F)[f]	80	80	80	80
Length of Use (in min) per day per person (TIME)[g]	5	5	5	5
Days per Year at Home (DAYh)[h]	352.25	352.25	352.25	352.25
Annual DHW Savings per Person	61.9	84.4	2.7	3.7
Annual DHW Savings per Person Weighted	81.8	kWH	3.7	therms
People per SF Home[i]	2.67	people	2.67	people
Sinks per SF Home[j]	3.83	sinks	3.83	sinks
Annual Savings per Aerator in SF Home	*57.0*	*kWH*	*2.6*	therms
People per MF Home[k]	2.14	people	2.14	people
Sinks per MF Home[l]	2.46	sinks	2.46	sinks
Annual Savings per Aerator in MF Home	*71.1*	*kWH*	*3.2*	therms

[a] Ameren Illinois HEP data PY1 compiled by Cadmus on 12/15/09

[b] Rated gpm for efficient aerators.

4 The other estimates included the following sources: Ohio TRM 2010, PA TRM 2010, Michigan Measure database, as prepared by Morgan Marketing Partners, 2011, "Energy Cost Calculator for Faucets and Showerheads." 1.9 GPM aerator, 2.0 GPM showerhead, all other input values as defaults.http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html#output , ComEd All Electric Single Family HEP Tune-Up Program Evaluation Report Draft-Octboer 5, 2010, Efficiency Vermont,TRM User Manual No. 2009-54, pgs 340-344, Dec 30,2008, NEEP Mid-Atlantic Technical Reference Manual Version 1.1, Oct 2010, prepared by VEIC.

[c] Average measured flow rates from HEP PY1 participants as measured prior to installation of aerators.

[d] http://energyexperts.org/EnergySolutionsDatabase/ResourceDetail.aspx?id=594

[e] For Chicago, IL: From Appendix D: Cold Water Inlet Temperatures, http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf

[f] Default Temperature of faucets in the Vermont TRM 2009 p. 280

[g] http://www.focusonenergy.com/files/Document_Management_System/Evaluation/renewableenergystandardcalculationrecommendationsrevised_evaluationreport.pdf

[h] Cadmus derived based on two weeks of vacation per year.

[i] DOE Residential Energy Consumption Survey (RECS) Table HC2.3: Household Characteristics by Type of Housing Unit (Millions of Households)

[j] From 12/21/09 Cadmus Group analysis of ComEd data from residential survey of 140 sites. (see sheet BH sinks.xls)

[k] DOE Residential Energy Consumption Survey (RECS) Table HC2.3: Household Characteristics by Type of Housing Unit (Millions of Households)

[l] From 12/21/09 Cadmus Group analysis of ComEd data from residential survey of 140 sites. (see sheet BH sinks.xls)

Showerheads

We calculated energy savings by assuming a decrease in flow rate through low-flow showerheads. This decrease in flow led to energy savings calculated for electric and gas water heaters, shown in Equations 3 and 4 below, respectively:

Equation 3:

Annual Electric DHW Savings (in kWh) per Person for showerheads = $(8.35*1*TIME*(FR_b-FR_e)*(T_{in}-T_{out})*DAY_h/3{,}413)/EFF_{elec}$

Equation 4:

Annual Gas DHW Savings (in therms) per Person for showerheads = $(8.35*1*TIME*(FR_b-FR_e)*(T_{in}-T_{out})*DAY_h/100{,}000)/EFF_{gas}$

Where the labeled variables are listed in Table 3 and the constants in the equations are:

- *8.35 lbs per gallon*
- *1 BTU/lb-degree F = amount of energy to raise 1 lb of water 1 degree F*
- *3,413 BTUs per kWh*
- *100,000 BTUs per therm*

The inputs into Equations 3 and 4, as well as the results of the savings calculation, are shown in Table 3. Since our previous evaluations in PY1 and PY2 we updated the flow rates from a baseline of 2.26 and efficient flow of 1.82 to the estimates provided in Table 3, below. These new estimates removed the assumption that flow rates are throttled as we found in a review of other studies[5] that flow rates were not throttled. We then multiplied annual savings per person by

[5] The other estimates included the following sources: Ohio TRM 2010, PA TRM 2010, Michigan Measure database, as prepared by Morgan Marketing Partners, 2011, "Energy Cost Calculator for Faucets and Showerheads." 1.9 GPM aerator, 2.0 GPM showerhead, all other input values as defaults.http://www1.eere.energy.gov/femp/technologies/eep_faucets_showerheads_calc.html#output , ComEd All Electric Single Family HEP Tune-Up Program Evaluation Report Draft-Octboer 5, 2010, Efficiency Vermont,TRM User Manual No. 2009-54, pgs 340-344, Dec 30,2008, NEEP Mid-Atlantic Technical Reference Manual Version 1.1, Oct 2010, prepared by VEIC

the number of people living in the home and divided by the number of sinks per home to derive an annual per aerator savings for either single or multifamily homes.

Table 3. Assumptions Used in Low-Flow Showerhead Calculation

Estimate of Default Saving for Low-Flow Showerheads		
Type of Water Heater	Electric	Gas
Efficient Showerhead Flow Rate (FRe)[a]	2	2
Baseline Showerhead Flow Rate (FRb)[b]	2.67	2.67
Water Heater Recovery Efficiency (EFF)[c]	100%	77%
Tin (in °F)[d]	53.9	53.9
Tout (in °F)[e]	105	105
Length of Shower (in min) per day per person (TIME)[f]	8.2	8.2
Days per Year at Home (DAYh)[g]	352.25	352.25
Annual Savings per Person (kWh,therms)	242.0	10.7
People per SF Home[h]	2.67	2.67
Showers per SF Home[i]	1.79	1.79
Annual Savings per Showerhead in SF Home (kWh,therms)	*361.0*	*16.0*
People per MF Home[j]	2.14	2.14
Showers per MF Home[k]	1.3	1.3
Annual Savings per Showerhead in MF Home (kWh,therms)	*398.4*	*17.7*

[a] Rated gpm for efficient showerheads.

[b] Average measured flow rates from HEP PY1 participants as measured prior to installation of efficient showerheads.

[c] http://energyexperts.org/EnergySolutionsDatabase/ResourceDetail.aspx?id=594

[d] For Chicago, IL: From Appendix D: Cold Water Inlet Temperatures, http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf

[e] A BPA study measured average shower temperatures 104 - 106. http://www.focusonenergy.com/files/Document_Management_System/Evaluation/renewableenergystandardcalculationrecommendationsrevised_evaluationreport.pdf And 105 is the Default Temperature of Showers in the Vermont TRM 2009 p. 278

[f] Report claims average shower length is 8.2 minutes: Mayer, P. W., De Oreo, W. B., Nelson, J. O., Opitz, E., and Allen, R. (1997) North American Residential End Use Study Progress Report . American Water Works Association Research Foundation, Denver, CO.

[g] Cadmus derived based on 2 weeks of vacation per year.

[h] DOE Residential Energy Consumption Survey (RECS) Table HC2.3: Household Characteristics by Type of Housing Unit

[i] From 12/21/09 Cadmus Group analysis of ComEd data from residential survey of 140 sites.

[j] DOE Residential Energy Consumption Survey (RECS) Table HC2.3: Household Characteristics by Type of Housing Unit (Millions of Households)

[k] From 12/21/09 Cadmus Group analysis of ComEd data from residential survey of 140 sites. (see sheet BH sinks.xls)

Appendix B: Pipe Insulation Assumptions

Only the pipe insulation assumptions from this memo are used in the PY3 savings results.

THE CADMUS GROUP, INC.

Date: **February 9, 2011**
To: **Karen Kansfield, Ameren Illinois**
From: **Robert Huang, The Cadmus Group Inc.**
Re: **Domestic Hot Water Savings Analysis Addendum to PY2 Multifamily and Home Energy Performance Reports**

In January 2010, Cadmus developed an engineering estimate of unit savings for domestic hot water (DHW) measures in follow up to the PY1 Home Energy Performance and Multifamily program evaluations. **The purpose of this memo is to describe how these results, shown in Table 1, were calculated.**

Table 1. Domestic Hot Water Unit Savings Summary

DHW Default Savings Estimates										
Type of Water Heater	Faucet Aerator				Low Flow Showerheads				Pipe Insulation	
	Single Family		Multifamily		Single Family		Multifamily		Single and Multifamily	
	Savings	Per	Savings	Per	Savings	Per	Savings	Per	Savings	Per
Electric (in kWh)	30	aerator	37	aerator	240	shower-head	264	shower-head	51	insulation job
Gas (in therms)	1.2	aerator	1.6	aerator	10.6	shower-head	11.7	shower-head	2.3	insulation job

Aerators

We calculated energy savings by assuming a decrease in flow rate through the aerators in both kitchen and bathroom faucets. This decrease in flow led to energy savings calculated for electric and gas water heaters, shown in Equations 1 and 2 below, respectively:

Equation 1:
Annual Electric DHW Savings (in kWh) per Person for bathroom and kitchen aerators = $(8.33*1*TFR_b*TIME*((TFR_b-TFR_e)/TFR_b)*(T_{in}-T_{out})*DAY_h/3{,}413)/EFF_{elec}$

Equation 2:
Annual Gas DHW Savings (in therms) per Person for bathroom and kitchen aerators = $(8.33*1*TFR_b*TIME*((TFR_b-TFR_e)/TFR_b)*(T_{in}-T_{out})*DAY_h/100{,}000)/EFF_{gas}$

Where the constants in the equation are:

- *8.33 lbs per gallon*
- *3,413 BTUs per kWh*
- *100,000 BTUs per therm*
- *1 BTU/lb-degree F = amount of energy to raise 1 lb of water 1 degree F*

The inputs into Equations 1 and 2, as well as the results of the savings calculation, are shown in the Table 2. We then weighted the annual DHW savings per person by the ratio of kitchen to bathroom aerator PY1 installs. We multiplied the annual weighted DHW savings per person by the number of people living in the home and divided by the number of sinks per home to derive an annual per aerator savings for either single or multifamily homes in the Ameren Illinois service territory.

Table 2. Assumptions Used in Aerator Calculation

Estimate of Default Saving for Aerators				
Type of Water Heater	Electric		Gas	
Measure Name	Kitchen Aerator	Bathroom Aerator	Kitchen Aerator	Bathroom Aerator
Number Installed at AIU	5	38	59	680
Efficient Aerator Throttled Flow Rate (TFRe)	1.84	1.48	1.84	1.48
Baseline Aerator Throttled Flow Rate (TFRb)	2.13	1.87	2.14	1.85
Water Heater Recovery Efficiency (EFF)	100%	100%	77%	77%
Tin (in °F)	53.9	53.9	53.9	53.9
Tout (in °F)	80	80	80	80
Length of Use (in min) per day per person (TIME)	5	5	5	5
Days per Year at Home (DAYh)	352.25	352.25	352.25	352.25
Annual DHW Savings per Person	32 kWh	44 kWh	1.5 therms	1.8 therms
Annual DHW Savings per Person Weighted	42.40	kWH	1.79	therms
People per SF Home	2.67	people	2.67	people
Sinks per SF Home	3.83	sinks	3.83	sinks
Annual Savings per Aerator in SF Home	*30*	*kWH*	*1.2*	therms
People per MF Home	2.14	people	2.14	people
Sinks per MF Home	2.46	sinks	2.46	sinks
Annual Savings per Aerator in MF Home	*37*	*kWH*	*1.6*	therms

Showerheads

We calculated energy savings by assuming a decrease in flow rate through low-flow showerheads. This decrease in flow led to energy savings calculated for electric and gas water heaters, shown in Equations 3 and 4 below, respectively:

Equation 3:

Annual Electric DHW Savings (in kWh) per Person for showerheads = $(8.33*1*TFR_b*TIME*((TFR_b-TFR_e)/TFR_b)*(T_{in}-T_{out})*DAY_h/3{,}413)/EFF_{elec}$

Equation 4:

Annual Gas DHW Savings (in therms) per Person for showerheads = $(8.33*1*TFR_b*TIME*((TFR_b-TFR_e)/TFR_b)*(T_{in}-T_{out})*DAY_h/100{,}000)/EFF_{gas}$

Where the constants in the equation are:

- *8.33 lbs per gallon*
- *3,413 BTUs per kWh*
- *100,000 BTUs per therm*
- *1 BTU/lb-degree F = amount of energy to raise 1 lb of water 1 degree F.*

The inputs into Equations 3 and 4, as well as the results of the savings calculation, are shown in Table 3. We then multiplied annual savings per person by the number of people living in the home and divided by the number of sinks per home to derive an annual per aerator savings for either single or multifamily homes.

Table 3. Assumptions Used in Low-Flow Showerhead Calculation

Estimate of Default Saving for Low-Flow Showerheads		
Type of Water Heater	Electric	Gas
Efficient Aerator Throttled Flow Rate (TFRe)	1.82	1.82
Baseline Aerator Throttled Flow Rate (TFRb)	2.26	2.26
Water Heater Recovery Efficiency (EFF)	100%	77%
Tin (in ^oF)	53.9	53.9
Tout (in ^oF)	105	105
Length of Shower (in min) per day per person (TIME)	8.2	8.2
Days per Year at Home (DAYh)	352.25	352.25
Annual Savings per Person	161 kWh	7.1 therms
People per SF Home	2.67	2.67
Showers per SF Home	1.79	1.79
Annual Savings per Showerhead in SF Home	*240 kWh*	*10.6 therms*
People per MF Home	2.14	2.14
Showers per MF Home	1.30	1.30
Annual Savings per Showerhead in MF Home	*264 kWh*	*11.7 therms*

Hot Water Pipe Insulation

We calculated heat loss per area of pipe for insulated and non-insulated water pipe via Equations 5 and 6 below:

Equation 5:

$Q/A_{ins} = (T_{pipe} - T_{amb})/R_{ins}$

Equation 6:

$Q/A_{unins} = (T_{pipe} - T_{amb})/R_{unins}$

Where:

- *Q/A = heat loss per area of pipe (BTU/hr-ft^2) for non-insulated and insulated pipe*
- *R = R-value of insulated and non-insulated pipe (hr- ft^2-degreeF/Btu)*
- *T_{pipe} = temperature of copper pipe*
- *T_{amb} = temperature of ambient air*

The inputs into Equation 5 and 6, as well as the results of the heat loss per area calculation, are shown in Table 4 below.

Table 4. Assumptions Used in Pipe Heat Loss Calculation

Pipe Heat Loss Assumptions		
Temperature of copper pipe (T_{pipe})	122	^oF
Temperature of ambient air (T_{amb})	67.5	^oF
R-value of un-insulated pipe (R_{unins})	0.86	hr-ft^2-^{o}F/Btu
R-value of insulated pipe (R_{ins})	2.79	hr-ft^2-^{o}F/Btu
Efficiency of electric hot water heater ($EFF_{electric}$)	100%	
Efficiency of gas hot water heater (EFF_{gas})	77%	
$AREA_{pipe}$	0.46	ft^2
Calculation		
Q/A $_{ins}$	19.47	Btu/hr-ft^2
Q/A $_{unins}$	63.18	Btu/hr-ft^2
Conversion to Gas and Electric Water Heater Savings		
Pipe Insulation Annual Electric and Gas Water Heater Savings	51	kWh
	2	therms

We calculated annual savings with Equations 7 and 8 below:

Equation 7:

Pipe Insulation Annual Electric Water Heater Savings = $(Q/A_{unins} - Q/A_{ins}) * AREA_{pipe} * 8{,}760)/EFF_{electric}/3{,}413$

Equation 8:

Pipe Insulation Annual Gas Water Heater Savings = $(Q/A_{unins} - Q/A_{ins}) * AREA_{pipe} * 8{,}760)/EFF_{gas}/100{,}000$

Where the constants in the equation are:

- *3,413 BTUs per kWh*
- *100,000 BTUs per therm*
- *8,760 hours per year*

The inputs into Equation 7 and 8, as well as the results of the annual savings calculations, are shown in Table 4 above.