TETRA TECH

Subject **Focus on Energy Evaluation**

ACES Deemed Savings Desk Review

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Introduction

The Apartment and Condo Efficiency Services (ACES) program offers a full range of energy efficiency services and measures to owners and managers of apartments and condominiums. These services are offered through three distinct program components: (1) New Construction, (2) Existing Whole Building, and (3) Existing In-unit Direct Install. Wisconsin Energy Conservation Corporation (WECC) and Franklin Energy, the program implementers, track the program's attributable savings for each installed measure using either project-customized savings calculations (i.e., custom savings) or prescribed savings values (i.e., deemed savings). Deemed savings are calculated using established formulas and estimated inputs based on primary and secondary research.

This memorandum presents the evaluation team's recommendations for updating several of the inputs to the deemed savings values for measures included in the Direct Install and Whole Building components of the ACES program. This research builds on the deemed savings review conducted by Patrick Engineering in 2008[1] and 2009[2].

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[1] Ron Swager and Chris Burger, Patrick Engineering. *ACES: Default Deemed Savings Review.* June 24, 2008.

[2] David Kramer, Ron Swager, and Chris Burger, Patrick Engineering. *Residential Programs: CY09 Deemed Savings Review.* March 26, 2010.

These recommendations are based on a combination of sources. Primarily, they are based on our findings from a desk review of the Existing Building forms completed by the Energy Advisors during site assessments and walk-through audits of multi-family buildings.[3] They also include findings from secondary research.

The remainder of this memo summarizes the background of this research effort including changes in scope agreed upon in May of 2010, key findings, the study methodology including sampling and data entry, and our findings and recommended deemed savings inputs on a measure-by-measure basis.

Background

In 2008 and then again in 2009, Patrick Engineering, at the direction of the Public Service Commission of Wisconsin (PSCW) and under the supervision of Tetra Tech (then known as PA Consulting Group), reviewed the deemed savings values of measures incentivized through the ACES program. These reports recommended that the evaluation team, in concert with program administrators, conduct additional research on several of the key inputs into the deemed savings calculation in order to strengthen the current default estimates.

As part of the CY10 detailed evaluation plan[4], the ACES evaluation activities included on-site measurements to provide revised inputs into the deemed savings calculations. The on-site measurements were to support the evaluation of three Direct Install measures: low-flow showerheads, faucet aerators, and CFLs. However, program staff made the decision to discontinue the Direct Install component of the program offerings on June 1, 2010. As these changes were not considered during CY10 evaluation planning, the evaluation team, the PSCW, and program staff agreed to replace the planned on-site visits with a more cost-effective paper and desk review of the key inputs into the deemed savings review assumptions.

WECC captures the water heater temperature, the flow rates for both existing showerheads and faucet aerators, and categorical data on lighting usage. Currently, several values from these forms are not being entered into the program-tracking database but are captured on the Existing Building forms.[5] The evaluation team worked in conjunction with the implementation contractors to randomly sample projects dating back to January 1, 2010, and create a database to capture information regarding those projects.

Key Findings

Our review of both primary data and secondary research built upon the 2008 ACES deemed savings review and revealed opportunities to strengthen estimates of some key input

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[3] Direct Install forms were also reviewed. However, the pertinent data contained on them was also contained on the Existing Building forms.

[4] The Focus on Energy Evaluation Team. *Evaluation Contract Year 2010 Detailed Evaluation Plans.* April 1, 2010.

[5] Existing Building forms are completed by Energy Advisors during the site assessment.

assumptions in the deemed savings calculations for low-flow showerheads, faucet aerators, and common area lighting. Below are key findings from the review.

- Based on a comparison of average groundwater temperatures from secondary sources, we recommend revising the current inlet water temperature estimate used for low-flow showerhead and faucet aerator savings from 50 degrees Fahrenheit to 48 degrees Fahrenheit. This change would have a positive effect on energy savings estimates for these water-saving measures.
- Average household size is used in the deemed savings calculations for low-flow showerheads and faucet aerators to estimate water consumption from these fixtures. The most recent results from the American Community Survey (2008) estimates an average household size of 2.10 persons for renter-occupied homes in Wisconsin, slightly higher than the assumption of 2.06 used in the most recent deemed savings review. As with inlet temperature, this change would have a small positive effect on energy savings.
- Existing flow-rates from a random sample of ACES Existing Building forms averaged 2.45 GPM for showerheads, 2.15 GPM for kitchen faucets, and 2.05 GPM for bath faucets. Each of these estimates is lower than the current assumptions and would lower water use and energy savings estimates.
- Applying all of the recommended updates to input assumptions for water-savings measures would result in approximately a two percent reduction in low-flow showerhead deemed savings and a one-and-a-half percent reduction in faucet aerator savings.
- Common area lighting savings are highly dependent on operating hours. The most recent deemed savings review assumes that indoor CFLs in common areas operate 24 hours/day. A review of indoor lighting usage recorded on ACES Existing Building forms and results from recent participants surveys indicate that this assumption likely overstates common area CFL usage and, by extension, energy savings estimates. We recommend a change from 21.6 hours per day to 16.3 hours per day for all common area CFLs.

Table 1 summarizes the evaluation team's recommended updates to input assumptions for these measures, based on the findings from our review. The rest of this document presents the research method for this analysis and detailed results.

Table 1. Summary of Recommended Updates to Key Inputs

Deemed Savings Input	Affected Measure(s)	Previous Recommendation	Updated Recommendation	Review Source(s)
Temperature of water entering water heater	Low-flow showerheads, faucet aerators	50℉	48℉	Comparison of secondary sources
Average household size	Low-flow showerheads, faucet aerators	2.06	2.10	2008 American Community Survey
Average flow rate of existing showerheads	Low-flow showerheads	2.50 GPM	2.45 GPM	Existing Building forms
Average flow rate of existing kitchen faucet	Faucet aerators	2.20 GPM	2.15 GPM	Existing Building forms
Average flow rate of existing bath faucet	Faucet aerators	2.20 GPM	2.05 GPM	Existing Building forms
Average operating hours for all common area CFLs	CFLs	21.6 hours per day	16.3 hours per day	Existing Building forms

Research Methodology

The following section describes our methodology for the deemed savings review.

Project Sampling and Entry

The initial goal of the desk review was to obtain hard copies of all Existing Building and Direct Install forms that Franklin Energy had collected since January 1, 2010. However, as Franklin Energy stores the original forms in three offices across the state, compiling copies of all forms proved to be impractical for this exercise. Instead, Franklin Energy provided the evaluation team with a list of all buildings at which an assessment had been conducted since January 1, 2010. From this list, we drew a random sample of 300 assessments. The sample was stratified based on the number of units per buildings: buildings with ten or fewer units (small buildings), buildings with more than ten but up to 30 units (medium buildings), and buildings with more than 30 units (large buildings). After sampling, we provided this list to Franklin Energy to collect the selected records from their files.

Data captured in the forms were entered into a Microsoft Access database by data entry staff. Ten percent of all forms were checked using double-blind entry and reviewed by a supervisor. This review identified an error rate of one percent. The errors were corrected.

Table 2 details the total number of forms in the initial list, the total sampled, missing, and entered for analysis. Program staff did not provide documentation for 23 requested properties.

Table 2. Desk Review Sampling Plan

Stratum	Number of Forms Since January 1, 2010	Number of Forms Sampled	Number of Forms Missing	Number of Forms Entered
Small Buildings (<=10 units)	356	125	5	120
Medium Buildings (>10 & <=30 units)	252	125	14	111
Large Buildings (>30 units)	106	50	4	46
Total	**714**	**300**	**23**	**277**

As we took a stratified random sample of the forms, our analysis of the collected data is weighted for disproportionate sampling. In addition, as forms occasionally contained information for several sample properties, our analysis is also weighted for the number of sampled properties each form represents. For example, if an entered form represented two properties, it carries twice the weight of an entered form that only represents a single property.

Secondary Research

Two data points are not captured in the on-site assessment forms: temperature of the water coming into the building ("input water temperature") and hot water usage. These values could not be reviewed as part of the desk review. Therefore, we relied on secondary internet research to capture these inputs.

We reviewed online literature from a variety of secondary sources to inform estimates on input water temperature and hot water usage. Average shallow ground water temperatures for different locations throughout the nation are well documented and can be used as a proxy for average input water temperature. We compared groundwater temperature data for Wisconsin from several sources, including data from the EPA and industry literature on ground-source heat pumps. Sources used for the analysis are referenced throughout the report.

While there is a mass of literature on water consumption, research on hot water usage, specifically related to shower and faucet use, is limited. Along with secondary literature, we also reviewed available primary research conducted on hot water use and behavioral preferences, including studies from the Bonneville Power Administration (BPA), the American Water Works Association (AWWA), and Energy Australia.

Results

The remainder of this memo presents detailed results from our review.

Low-flow Showerheads

Deemed savings assumptions for low-flow showerheads were last reviewed in 2008.[6] Based on recommendations from that report and discussions with program administrators, the

[6] Ron Swager and Chris Burger, Patrick Engineering. *ACES: Default Deemed Savings Review.* June 24, 2008.

evaluation team reviewed several key assumptions in the energy savings calculation, including existing showerhead flow-rate, input water temperature, and hot water usage parameters.

In the 2008 review, Patrick Engineering assumed 2.5 GPM for the average existing showerhead flow-rate based on federal code requirements for faucet fixtures. We used existing flow rate measurements recorded on the Existing Building forms by program Energy Advisors to calculate a revised estimate that is more representative of actual existing flow-rates in the program population. Based on measurements from 160 sites, the average existing showerhead flow rate was 2.45 GPM, slightly below federal code.

For input water temperature (the temperature of the water entering the water heater), the 2008 review used an estimate of 50 degrees Fahrenheit. As mentioned above, we used average groundwater temperature as a proxy for input water temperature. According to the EPA's map of groundwater temperatures across the nation, average groundwater temperatures in Wisconsin generally range from 42 degrees Fahrenheit to 52 degrees Fahrenheit.[7] A Geo-Heat Center report estimates an average statewide groundwater temperature of 46 degrees Fahrenheit.[8] In addition, a geothermal design guide from McQuay International, which reports groundwater temperatures for several US cities, lists 47 degrees for Milwaukee and 48 degrees for La Crosse[9]. Based on these data, we recommend an estimate of 48 degrees Fahrenheit for input water temperature.

Another key input in the deemed savings calculation is average household size, which is used to estimate the number of showers per day per fixture. The 2008 deemed savings review used a value of 2.06 persons per household, based on 2006 American Community Survey (ACS) data. The 2008 ACS provides a more recent estimate of 2.10 persons per household for renter-occupied units in Wisconsin.[10]

Table 3 presents our recommended updates to key assumptions based on our review and the corresponding impact on recommended deemed savings values (using the same algorithm used in the 2008 review). Revisions to these inputs decrease the estimated savings by approximately two percent.

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[7] Environmental Protection Agency. *Correcting the Henry's Law Constant for Soil Temperature*. Fact Sheet. June 2001.

[8] Lund, John W. *Geothermal Heat Pump Utilization in the United States*. Geo-Heat Center.

[9] McQuay International. *Geothermal Heat Pump: Design Manual*. Application Guide 31-008. 2002.

[10] 2008 American Community Survey. Selected Housing Characteristics: Wisconsin. http://factfinder.census.gov/.

Table 3. Low-flow Showerhead Deemed Savings Input Review Results

Parameter	2008 Review Estimate	Review Findings
Average flow rate of existing showerheads	2.50 GPM	2.45 GPM
Temperature of water entering water heater	50℉	48℉
Average household size	2.06	2.10
Average shower duration	8 minutes	No change
Temperature of water at point of use	105℉	No change
Annual savings (electric water heater)	544.8 kWh	533.3 kWh
Annual savings (gas water heater)	27.2 therms	26.6 therms

We also conducted secondary research on two other key inputs in the low-flow showerhead savings calculation relating to hot water usage: the average water temperature at point of use and the average duration of a shower. Patrick Engineering estimated an average shower temperature of 105 degrees Fahrenheit and average shower duration of 8.0 minutes, based on water use studies conducted by AWWA, BPA, and Energy Australia. After reviewing these studies and conducting additional internet research, we do not recommend any changes to these estimates. The evaluation team was unable to find any additional studies on shower duration other than the studies reviewed in the 2008 report. In addition, a recent primary research effort on another residential population yielded results consistent with the current estimate.

Measures such as showerheads and faucet typically use a mix of hot and cold water. In the absence of reliable data on the ratio of hot and cold water mixing, one can apply the difference between the inlet water temperature and the point-of-use water temperature (instead of the temperature of the water leaving the water heater). The BPA's *Multi-family Showerhead and Faucet Aerator Metering Study* (1999) measured shower temperatures in 93 units and found average shower temperatures ranging from 104.2 to 106.4 degrees Fahrenheit.[11] Another study with seven participants yielded similar results, finding an average shower temperature of 104 degrees Fahrenheit.[12]

Faucet Aerators

The 2008 deemed savings review included recommendations for kitchen and bath faucet aerators. For this review, we examined several key inputs in the deemed savings calculation for aerators, including existing faucet flow rates and assumptions used in estimating faucet water usage. We also applied the updated estimates for inlet water temperature and household size, as described above.

One critical input in deemed savings calculation is the duration of faucet use. The previous deemed savings review assumes five minutes/day/person for total faucet use. This estimate was based off findings from the American Water Works Association's Residential End Uses of

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[11] SBW Consulting, Inc. *Energy Efficient Showerhead and Faucet Aerator Metering Study Multifamily Residences: A Measure and Evaluation Report*. October 1994.

[12] Parsons, Kenneth C. *Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Heath, Comfort and Performance.* October 27, 1993.

Water study. [13] The report divides this value into three minutes/day/person for kitchen faucets and two minutes/day/person for bathroom faucets. We did not locate any research on the relative usage of kitchen faucets versus bath faucets; however, estimates on total faucet use from another water use study were in line the previous assumption. An EPA study of ten Seattle households found an average faucet usage of 22.4 gallons/day, which translates into about 4.8 minutes/day/person using a flow rate of 2.2 GPM and the average household size for renter-owned homes in Wisconsin[14]. Based on these findings, we do not recommend any changes to the duration of use.

The 2008 deemed savings review also assumed the point-of-use water temperature for faucets to be the same as for showerheads. The evaluation team was unable to locate any research on point-of-use temperatures, nor ratios of hot to cold water, for faucets. Lacking additional information, we recommend no changes to the point-of-use temperature assumed for faucets in the 2008 report.

Next, we summarize our recommended changes to input assumptions used for kitchen and bath faucet aerators, and their impact on the deemed savings values recommended in the 2008 report.

Kitchen Faucet Aerators

The previous deemed savings review assumed a 2.20 GPM flow rate for all faucets, based on requirements from the 1992 Federal Energy Policy Act. The Existing Building forms collect existing flow rates for both kitchen faucets and bath faucets individually. Of the 152 site forms where the flow rate for kitchen faucets was recorded, the average flow rate was 2.15 GPM, slightly less than the previously assumed value. Table 4 summarizes recommended changes to key input assumptions and their impact on the deemed savings for kitchen aerators, based on the review findings. The impact to the savings are marginal at best.

Table 4. Kitchen Faucet Aerator Deemed Savings Input Review Results

Parameter	2008 Review Estimate	Review Findings
Average flow rate of existing faucet	2.20 GPM	2.15 GPM
Temperature of water entering water heater	50℉	48℉
Average household size	2.06	2.10
Duration of faucet use	3 minutes/day/person	No change
Temperature of water at point of use	105℉	No change
Annual savings (electric water heater)	223.1 kWh	219.9 kWh
Annual savings (gas water heater)	11.1 therms	11.0 therms

[13] American Water Works Association Research Foundation. *North American Residential End Use Study Progress Report.* 1997.

[14] William B. DeOreo, et al. *The End Uses of Hot Water in Single Family Homes From Flow Trace Analysis.* Aquacraft, Inc. Undated.

Bath Faucet Aerators

For bath aerators, 155 site forms recorded existing flow rates, averaging 2.05 GPM. The difference in flow rates per the review findings intuitively makes sense when compared with the kitchen faucets; one would expect the average flow rate of bath faucets to be lower than kitchen faucets, which it is. Table 5 shows recommended changes to input assumptions for bath faucet aerators and their impact on the deemed savings estimates.

Table 5. Bath Faucet Aerator Deemed Savings Input Review Results

Parameter	2008 Review Estimate	Review Findings
Average flow rate of existing faucet	2.20 GPM	2.05 GPM
Temperature of water entering water heater	50℉	48℉
Average household size	2.06	2.10
Duration of faucet use	2 minutes/day/person	No change
Temperature of water at point of use	105℉	No change
Annual savings (electric water heater)	127.1 kWh	105.9 kWh
Annual savings (gas water heater)	6.3 therms	5.3 therms

Common Area Lighting

Although not a component of the Direct Install program, we also reviewed common area lighting savings included in the Whole Building program component. Common area lighting is directly installed and highlighted by Patrick Engineering as a technology that should be reviewed in greater depth. In the 2008 ACES deemed savings review, common area lighting was segmented into three categories of lighting replacements for analysis: direct replacement of incandescents with CFLs, replacement of incandescent and fluorescent exit signs with LED or electroluminescent signs, and an “other” category including linear fluorescent upgrades and fixture replacements. For this review, the evaluation team analyzed data collected on the Existing Building forms to inform usage estimates for only the CFL replacement category. We did not review operating hours for exit sign replacements, as we assume these fixtures to operate 24 hours/day. The 2008 report breaks out operating hours for the “other” lighting category by whether or not the lighting is automatically controlled. Due to the lack of availability of this data, we did not conduct any further research on usage estimates for this category.

The Existing Building forms collect information on existing lighting, including the number of bulbs installed and whether the bulbs operate 24 hours/day, for lighting in different types of common areas. Lighting areas listed on the form include exit lights, exterior, hallway, laundry, basement/garage, and “other” common areas. In addition, there is open spot for the Energy Advisor to write down the type and wattage of lighting; however, this information varied in completeness and level of detail. As a result, we used all available lighting data to review usage, regardless of type.

The 2008 report recommends a default annual deemed savings value of 409 kWh and a peak demand reduction of 41.5 watts/lamp.[15] These estimates are based on an average usage of 21.6 hrs/day, which was calculated assuming 20 percent exterior operation at 12 hrs/day and 80 percent interior operation at 24 hrs/day. This proportion of exterior to interior CFL installations was averaged from ACES installations from the summer of 2007 through the spring of 2008.

We used the data from the Existing Building forms to review the 24-hour operation assumption for interior lighting. The form includes a check box for whether or not the lighting in a given common area type is operating 24 hrs/day. Weighting by the proportion of bulbs recorded for each common area type, the forms indicated 24 hr/day operation for 44.4 percent of the indoor lighting. The forms do not capture the number of hours of operation if not 24 hours per day.

Number of hours operating hours drives the energy savings values significantly. For example, assume an operating time of 12 hours for the remaining indoor lighting. With this assumption, the average indoor lighting usage would be 17.3 hrs/day. As Table 6 shows, this assumption would reduce the savings from 409 kWh to 308 kWh.

Table 6. Common Area CFL Operating Hours and Deemed Savings Comparison

Parameter	2008 Review Estimate	Existing Building Results*
Average operating hours for indoor CFLs	24.0	17.3
Average operating hours for all common area CFLs	21.6	16.3
Annual savings (kWh)	409	308

* Assuming 12 hours for lights not operating 24 hrs/day

Other sources, including 2009 participant surveys, 2003 participant surveys, and other evaluations of multi-family programs also suggest that an estimate of 21.6 operating hours per day for common area CFLs is too high. The CY09 ACES participant survey also asked respondents about typical operating hours for lighting common areas of their buildings. A considerable proportion of participants indicated that their building's common area lighting typically operated much less than 24 hours/day. Thirty-six percent of respondents (28 of 77) reported that their common area lighting operated, on average, about 70 hours per week (10 hours per day) or less during the majority of months throughout the year.

In addition, as part of 2003 evaluation efforts, Innovologie conducted a survey with participants in the ACES program. As part of this survey, respondents reported on the hours of operation in common areas of the CFLs they received as part of the program. Innovologie found that the average operating hours for CFLs installed outside of tenants' units was 16.1 hours per day.[16]

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[15] The evaluation team notes a discrepancy in the 2008 ACES deemed saving review report between the recommended deemed savings value of 407 kWh reported on page 2-1 and 409 kWh reported on page 2-2.

[16] John Reed and Jeff Riggert, Innovologie, LLC. *The Use and Energy Savings from Compact Fluorescent Lamps Purchased through the Apartment and Condominium Efficiency Services ENERGY STAR® Products Program: Results of a Participant Survey*. November 6, 2003.

In the resulting report, the evaluation team referenced estimates calculated as part of an evaluation of NSTAR's Small Commercial and Industrial programs.[17] In that study, participants in multi-family properties reported that common area usage of CFLs was 17.3 hours per day. Metering conducted as part of the evaluation estimated 15.0 hours per day.

These findings suggest the 24 hour/day operation assumption for indoor common area CFLs is likely too high, resulting in overstated deemed savings. Based on our desk review of the Existing Building forms and consistent research from both previous ACES evaluations and other multi-family program evaluations, we recommend changing the average operating hours for all common area CFLs to 16.3 hours per day. However, the evaluation team feels that additional primary research on lighting operating hours, through either building manager interviews or metering, would inform a more accurate estimate.

[17] Thomas Ledyard and Susan Haselhorst. "Evaluating the Underserved Small C&I Market: Building a Bridge to Implementation." *Proceedings of the International Energy Program Evaluation Conference*. Seattle, WA: August 2003, pp. 627–637.