State of Wisconsin Public Service Commission of Wisconsin

Focus on Energy Evaluation

ACES: Default Deemed Savings Review

Final Report: June 24, 2008

Evaluation Contractor: PA Government Services Inc.

Prepared by: Ron Swager and Chris Burger, Patrick Engineering

focus on energy[sm]

The power is within you.

State of Wisconsin
Public Service Commission of Wisconsin

Focus on Energy Evaluation

ACES: Default Deemed Savings Review

Final Report: June 24, 2008

Liaison Contact: Dr. David Sumi
PA Government Services Inc.
6410 Enterprise Lane, Suite 300
Madison, WI 53719
Tel: +1 608 443 2700
Fax: +1 608 661 5181
E-mail: David.Sumi@paconsulting.com

Prepared by: Ron Swager and Chris Burger, Patrick Engineering

Acknowledgment: Pam Rathbun and Bryan Ward, PA Government Services Inc., and Ralph Prahl, Prahl & Associates, contributed critical review and analysis.

This report is the property of the state of Wisconsin, Public Service Commission of Wisconsin, and was funded through the Wisconsin Focus on Energy Program.

FOREWORD

The Apartment and Condominium Efficiency Services (ACES) program consists of a whole building existing and a new construction component. Each component contains both prescriptive and custom incentives. The custom incentive structure has two tiers for both existing building and new construction projects, with the Tier 2 incentives based on implementation of multiple incentive categories to encourage more comprehensive installations.

Through December 31, 2007, ACES accounted for over 50 percent of the total unverified gross therm savings for all of the residential programs combined, 18 percent of the unverified gross demand kW savings, and 17 percent of the unverified gross kWh savings.

Evaluation efforts during the second half of 2007 and early 2008 focused on reviewing deemed savings values and their underlying assumptions for the following measures:

- Whole Building Existing, In Unit Direct Install—CFL replacement
- Whole Building Existing, In Unit Direct Install—Low-flow showerheads
- Whole Building Existing, In Unit Direct Install—Faucet Aerators
- Whole Building Existing, Whole Building—Prescriptive CFL, cold cathode or LED lamp replacement
- Whole Building Existing, Whole Building—90+ efficiency modulating boiler replacements
- New Construction—90+ efficiency modulating boiler replacements.
- New Construction—Common Area Lighting

This document presents the evaluator’s recommendations for maintaining or changing deemed savings values for each of these measures based on our review.

TABLE OF CONTENTS

1. WHOLE BUILDING EXISTING, IN UNIT DIRECT INSTALL PROGRAM

Under the In Unit Direct Install Program, after consulting with the building owner(s), ACES contractors will replace existing incandescent light bulbs with compact fluorescent lamps (CFLs) and replace showerheads and faucet aerators with new low-flow versions throughout all dwelling units in the building. Outdoor and common area lighting and common area utilities are covered under the ACES Whole Building Program.

For each measure where the deemed savings values and assumptions were reviewed through this program, we first summarize the current default savings being used, our recommendations for changes to the current default savings, and a general discussion of prior studies and other assumptions used when evaluating the current default savings. This is followed by our recommendations for further study to strengthen the current or recommended default savings estimate.

1.1 COMPACT FLUORESCENT LAMP (CFL) REPLACEMENTS

Current default savings: The default savings value for direct-install CFLs currently in use by ACES is 43.5 kWh/yr (taken from the ACES database). This figure was taken from the residential program and is based on the assumptions of an average savings of 51.9 watts/lamp, operating at 2.7 hours/day, with an adjustment for an 85% install rate. ACES also uses a peak demand load reduction resulting from CFL installations of 3.1 watts/lamp based on an assumed 7% coincidence factor.

Recommendation for change in deemed savings: No change in the deemed savings value of 43.5 kWh/yr is recommended. However, the rate of 3.1watts/lamp for peak demand load reduction should be increased to 4.2 watts/lamp.

Analysis and references: The calculation of annual energy savings for CFL replacements requires evaluating both the average number of hours of operation of the installed CFLs and the average wattage reduction achieved from that of incandescent lamps.

The US EPA ENERGY STAR savings calculator uses 4 hours/day as a typical operating time for residential applications. This value comes from *The Lighting Pattern Book for Homes* by the Lighting Research Center.[1] However, the Focus 2002 report[2] suggests an average of 3.5 hours/day as a typical operating time and an average savings of 51.9 watts/lamp.

Table 1-1, adapted from the Focus 2002 report, shows the assumptions or results from other evaluations of CFL usage. The gross value in Table 1-1 represents the savings from an average CFL replacing a similar output incandescent. The “adjusted” value represents a correction for a certain percentage of the distributed CFLs assumed either not installed or

---

[1] The Lighting Research Center. *The Lighting Pattern Book for Homes.* Rensselaer Polytechnic Institute. 1993.

[2] Darren Schauf, Jennifer Mitchell-Jackson, Opinion Dynamics Corporation. *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Statewide Evaluation, ENERGY STAR Labeled Products Program. Evaluation of Deemed Energy Savings Estimates for ENERGY STAR-labeled Products*. August 14, 2002.

removed after installation. A savings of zero is assumed for this percentage of the lamps in the per unit calculation. The adjusted value may also include savings lost to the space heating system to make up for reduced heat gain from the lighting system.

Table 1-1. Summary of CFL Savings Assumptions

Administrator/ Utility/Study	Year	Basis	Gross Per Unit kWh Savings	Per Unit kWh Savings Used (Adjusted)	Avg. Hours of Operation /Day	Watts Saved
DOE/EIA[1]	1996	Survey			6.7	
NWEEA	1996	Evaluation	(97)	66[2]	3.6	74
MA Utilities-Regional Analysis	1999	Starlight Report (XENERGY)	68		3.4	54.8
NGRID	1999	Based on the MA Study	68		3.4	54.8
Northeastern Utilities	1999	Evaluation	(63)		3.6	48
New Jersey Utilities		Based on the MA Study	(68)	61[3]	3.4	54.8
NYSERDA		Based on the MA Study	68		3.4	54.8
Minnesota			66		4.0	45
PG&E	2001		66.5		3.5	(52)
VT	2001	Program Data	58.1		3.4	46.8[4]
NW RTF	2002	Weighted Sales Data	(96)	71[5]	3.6	73
Focus	2002	Hours from National ENERGY STAR and Average Watts Saved	76		4.0	51.9
Nexus for Ma, RI, VT[6]	2004	Residential Long term logging study	40.2		2.7± 17.7% includes outdoor	48.7± 5%
KEMA/XENERGY[7]	2005	Statewide metering study			2.28 – indoor 2.36 – includes outdoor	

[1] Residential Lighting Use and Potential Savings, September 1996, DOE/EIA-0555(96)/2
[2] Adjusted by a factor of 80% to account for in-service rate and by a factor of 85% to account for space heating interactions.
[3] Adjusted by a factor of 90% to account for in-service rate.
[4] Based on data from products rebated during program year 2001.
[5] Assumes 12% removal.
[6] Nexus Market Research, Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs, Oct. 2004.
[7] KEMA-XENERGY. CFL Metering Study: Final Report. Prepared for the California investor owned utilities. 2005.

A review of the available literature by SERA[3] found the average hours of use of CFLs to be about 2.28 hours per day. Including outdoor CFLs increases the average hours of use to 2.34

[3] Lisa A. Skumatz, Skumatz Economic Research Associates, Inc. and Owen Howlett, Heschong-Mahone Group. *Findings and "Gaps" in CFL Evaluation Research: Review of the Existing Literature.* 2006.

hours per day. Table 1-2 shows results from the KEMA-XENERGY study[4] that measured the usage of lamps installed in various rooms in single and multi-family residences. The results suggest a much lower daily usage of CFLs than that assumed for most of the earlier studies shown in Table 1-1.

Table 1-2. CFL Hours of Use per Day by Room Type (KEMA 2005)

Location	Average # Hours/Day
Bedroom	1.6
Bathroom	1.5
Family room	2.5
Garage	2.5
Halls/entry	1.6
Kitchen	3.5
Living room	3.3
Laundry room	1.2
Other room	1.9
Outdoor	3.1
Overall Average	**2.3**

Earlier studies often assumed that because of the high cost of CFLs, they would be preferentially installed in high use areas to maximize energy savings. However, because of the direct install nature of the ACES CFL replacement program, the KEMA results may be more applicable. ACES contractors install CFLs throughout the dwelling units and not just in high usage areas. The installations in lower usage areas will pull down the average daily usage per lamp.

While it could be argued that apartments and condominiums would experience additional usage as they will typically have less access to natural daylighting, the KEMA report compared its metering results for single- and multi-family residences and found that multi-family residents showed only a slight, and not statistically significant, increase in use of approximately 4 minutes/day over single family residences.

Based on this prior research, we recommend that 2.3 hours/day be used for in-unit CFL replacements resulting from the ACES direct install program.

To obtain an estimate of the average watts saved by replacing incandescent lamps, Patrick Engineering assumed the following replacements after a review of CFLs available at retail stores:

---

[4] KEMA-XENERGY. *CFL Metering Study: Final Report.* Prepared for the California investor owned utilities. 2005.

Table 1-3. Replacement Assumptions

Incandescent lamp	Replacement CFL	Watts saved
40 watts	9 watts	31
60 watts	15 watts	45
75 watts	19 watts	56
100 watts	26 watts	74
Average		**51.5**

Assuming an equal number of replacements of each wattage are made, the average savings is 51.5 watts/lamp. The Delta Watts report[5] prepared for the residential lighting program by Glacier Consulting calculated a weighted average based on the distribution of CFLs rewarded in FY07 under the residential program. They found that the average gross savings is 53.3 watts for CFLs purchased via instant rewards and 55.0 watts for CFLs purchased via mail-in rewards.

The direct install nature of the ACES program would likely result in a different distribution of installed CFL wattages than the residential program. It is assumed that contractors will buy and install a limited number of CFL sizes in bulk, rather that picking and choosing from the range of sizes and brands as a homeowner might under the residential program. Until similar data on the purchase of CFLs by wattage under the ACES program is available to enable a refined, weighted average to be calculated, it is recommended that 51.9 watts/lamp continue to be used for calculating the deemed energy savings.

The annual savings then becomes:

51.9 watts/lamp x 2.3 hrs/day x 365 days/yr ÷ 1000 watts/kW = ***43.5 kWh/yr***

The resulting deemed savings is assumed to be a conservative estimate.

ACES also estimates the peak demand load reduction resulting from CFL installations as 3.1 watts/lamp. While individual lamps may save 50 watts or more in demand load, the load reduction is averaged over all installed lamps whether they would typically operate during the demand period or not. The current default savings is based on an assumption of a 0.07 coincidence factor--i.e. approximately seven percent of the installed CFLs would replace bulbs in operation during the peak demand period (Monday-Friday, 1-4 p.m., June–August).

The Nexus 2004[6] report estimated a summer coincidence factor of 0.121 ± 19.6% in Massachusetts, Rhode Island, and Vermont from logger data. The New England State

---

[5] Tom Talerico and Rick Winch, Glacier Consulting Group, LLC. *Analysis of Delta Watts Values for CFLs Rewarded through the Residential Lighting Program during FY07*. Prepared for the Wisconsin Focus on Energy Evaluation. March 6, 2008.

[6] Nexus Market Research. *Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs.* October 2004.

Program Working Group 2007 Study[7] measured monthly summer coincidence factors of between 0.069 and 0.092, averaging 0.082 ± 6.1% over June, July, and August. The KEMA 2005[8] report from California found summer weekday coincidence factors to be approximately 0.075. Based on the 2007 New England Study and the similar climates of Wisconsin and New England, it is recommended that the coincidence factor be increased to 0.082 and the deemed savings for peak load reduction increased to 4.2 watts/lamp.

Recommendations for further study: Data on the wattage of CFLs and the wattage of bulbs they are replacing should be tracked by ACES in order to reduce the uncertainties in the per-lamp savings as was done in the Residential program. An actual metering study of lamp usage in Wisconsin would better establish the hours of use and time-of-day demand reducing the uncertainties introduced by using data from other states.

1.2 LOW-FLOW SHOWERHEADS

Current default savings: ACES currently uses 25 therms/year as the default savings value for replacing showerheads in buildings with gas water heaters, and 553 kWh/year for replacing showerheads in buildings with electric water heaters. This analysis was unable to identify the assumptions that were used to derive these figures. However, in the late 1990s, both Wisconsin Electric (We Energies) and Wisconsin Power & Light (Alliant) performed direct installation of energy efficient showerheads. Wisconsin Electric assumed a savings of 493 kWh/yr. Wisconsin Power & Light assumed a savings of 594 kWh and 28 therms (taken from the deemed numbers in the FOE 2002 deemed savings report). These calculations were based on replacing 3.0 gallon/minute showerheads with 2.5 gallon/minute lower-flow models. However, currently the baseline is assumed to be 2.5 gallon/minute reducing to 1.75 gallon/minute.

Recommendation for change in deemed savings: It is recommended that the default deemed savings be adjusted to 27.2 therms and 544.8 kWh per year. These adjustments reflect the changing baseline assumptions and the inclusion of the average multi-family household size to estimate the number of showers daily

Analysis and references: For this calculation, Patrick Engineering adapted a spreadsheet provided by Franklin Electric. A sample calculation with the indicated assumptions is illustrated below.

---

[7] RLW Analytics. *Coincidence Factor Study – Residential and Commercial & Industrial Lighting Measures*. Prepared for New England State Program Working Group. Spring 2007.

[8] KEMA-XENERGY. *CFL Metering Study: Final Report*. Prepared for the California investor owned utilities. 2005.

Energy and Water Savings by Installing Low Flow Showerheads
Assumptions: 2.5 gpm; average flow rate of existing showerheads[1] 1.75 gpm; flow rate of new Niagara low flow showerheads 8.0 mins; average duration of a shower 105°F; temperature of water at point of use[2.] 50°F; temperature of water entering water heater 65% average estimated efficiency of natural gas water heater(s) [3] 2.06 Average Household size (persons) [4.] 1.17 Average # of fixtures per unit [5] 1.0 Showers per day per person 1.76 Showers per day per fixture = 2.06 person/unit x 1 shower/person/day ÷ 1.17 fixture/unit **Annual water usage with current showerheads:** 2.5 gpm X 8 mins X 1.76 showers/day/fixture X 365 days = 12,848 gallons/yr/fixture **Annual water usage with low-flow showerheads:** 1.75 gpm X 8 mins X 1.76 showers/day/fixture X 365 days = 8,994 gallons/yr **Annual savings with low-flow showerheads:** 3,854 gallons hot water saved per fixture X 8.33 lb/gal X 1 Btu/lb-°F X 55°F DT = 1,766,000 BTU = 17.7 therms 1,766,000 BTU ÷ 65% efficiency = 2,717,000 BTU = 27.2 therms saved per year
Notes: 1. The baseline is taken from the Federal Energy Policy Act of 1992 that mandates that "all faucet fixtures manufactured in the United States restrict maximum water flow at or below 2.5 gallons per minute (gpm) at 80 pounds per square inch (psi) of water pressure or 2.2 gpm at 60 psi." 2. BPA study[1] measured average shower temperatures at 104–106º F. 3. Average efficiencies for gas and electric storage water heaters were taken from: American Council for an Energy Efficient Economy, *Consumers Guide to Home Energy Saving*, 2007. 4. 2006 American Community Survey data from the US census for Wisconsin gives an average household size of 2.06 persons in rental units. 5. 2001 Residential Energy Consumption Survey from the Energy Information Administration provides that 1.17 bathrooms/unit is the national average for owner occupied or rental units in buildings with two or more units.

These estimates by Patrick Engineering show a savings of approximately ***27.2 therms*** saved per year per fixture with the use of low flow showerheads. Repeating this calculation with an average electric water heater efficiency of 95% and converting BTUs to KWh results in ***544.8 kWh*** of electricity saved per year with the use of low flow showerheads. It is noteworthy that added data inputs of a household size of 2.06 persons per unit and 1.17 bathrooms/unit were incorporated into the analysis—resulting in more than one shower per day per fixture.

The average time a person spends in the shower daily is a critical number in this calculation. The US EPA Water Conservation Plan Guidelines[9] suggests 5–15 minutes per person per

[9] US Environmental Protection Agency. *Water Conservation Plan Guidelines*. EPA-832-D-98-001. August 6, 1998.

shower and the AWWA[10] study of 12 American cities indicates that the average shower lasted for 8.2 minutes at an average flow rate of 2.1 gallons per minute (gpm). A recent consumer study by EnergyAustralia[11] showed that 62 percent of people showered once a day, 29 percent twice a day, and nine percent showered three times a day (an average of 1.47 showers/day/person). The average Australian shower lasted seven minutes and eight seconds during the week and seven minutes and 44 seconds on the weekend.

In lieu of Wisconsin-specific data on shower habits, the deemed calculation will assume an average shower length of 8.0 minutes/day and only one shower per person per day.

Recommendations for further study: It is recommended that field installers perform random sample measurements of the flow rates from existing showerheads to better establish a baseline. The AWWA study of residential water use covered 12 cities, but none of these were in the Midwestern US. Local data on water use habits both before and after retrofitting would enable an improved calculation by reducing the uncertainty in the assumptions.

1.3 FAUCET AERATORS

Current default savings: The current ACES default deemed savings for the installation of low flow faucet aerators are shown in the Table 1-4.

Table 1-4. Default Deemed Savings for Low Flow Faucet Aerators

Application	Annual Default Energy Savings
Faucet Aerator - Bath - Electric	160.8 kWh
Faucet Aerator - Bath – Gas	10 therms
Faucet Aerator - Kitchen - Electric	158.8 kWh
Faucet Aerator - Kitchen – Gas	10 therms

This analysis was unable to determine the exact assumptions used to derive these figures. However, in the late 1990s, both Wisconsin Electric (We Energies) and Wisconsin Power & Light (Alliant) performed direct installation of energy efficient faucet aerators. Wisconsin Electric used 189 kWh for the expected savings. Wisconsin Power & Light used a savings of 142 kWh and 4 therms (from the deemed numbers in the FOE 2002 deemed savings report).

---

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

[11] EnergyAustralia. *Shower timers help families become energy efficient.* News Pager 02 9966 7985. October 22, 2006.

Recommendation for change in deemed savings: It is recommended that the default values be adjusted as shown in Table 1-5.

Table 1-5. Recommended Changes to Default Deemed Savings for Low Flow Faucet Aerators

Application	Annual Default Energy Savings
Faucet Aerator - Bath - Electric	127.1 kWh
Faucet Aerator - Bath – Gas	6.3 therms
Faucet Aerator - Kitchen - Electric	223.1 kWh
Faucet Aerator - Kitchen – Gas	11.1 therms

Analysis and References: For this calculation, Patrick adapted a spreadsheet provided by Franklin Electric. A sample calculation with the indicated assumptions is illustrated below.

Energy and Water Savings by Installing Low Flow Aerators

Assumptions:

2.2 gpm; average flow rate of existing aerators[1]
1.5 gpm; flow rate of new low flow aerators
3.0 mins; average daily use of a faucet aerator per person
105 °F; temperature of water at point of use
50 °F; temperature of water entering water heater
65%; average efficiency of water heater(s)
2.06; average household size (persons) [2]
1.0; average # of fixtures /unit[3]

Annual water usage with current aerators:

2.2 gpm X 3 mins/person X 365 days X 2.06 persons ÷ 1.0 fixtures/unit = 4,963 gallons/yr

Annual water usage with low-flow aerators:

1.5 gpm X 3 mins/person X 365 days X 2.06 persons ÷ 1.0 fixtures/unit = 3,384 gallons/yr

Annual energy savings with low-flow aerators:

1,579 gallons hot water saved per unit X 8.33 lb/gal X 1 Btu/lb °F X 55 °F ΔT = 723,400 BTU
= 7.23 therms

723,400 BTU ÷ 65% eff. = 1,113,000 BTU = 11.1 therms saved per year

Notes:

1. The baseline is taken from the Federal Energy Policy Act of 1992 that mandates that "all faucet fixtures manufactured in the United States restrict maximum water flow at or below 2.5 gallons per minute (gpm) at 80 pounds per square inch (psi) of water pressure or 2.2 gpm at 60 psi."
2. 2006 American Community Survey data from the US census for Wisconsin gives an average household size of 2.06 persons in rental units.
3. 2001 Residential Energy Consumption Survey from the Energy Information Administration gives the national average of 1.17 bathrooms/unit for owner occupied or rental units in buildings with two or more units.

The results of repeating the calculation above for bath faucets (at 2 min/day/person usage) and for electric water heaters (95% efficiency, with the necessary conversion of the results to kWh) are shown in Table 1-6.

Table 1-6. Estimated Energy Savings for Water Heaters

Faucet location	Min/day/person	Water heater type	Water heater efficiency	# of Fixtures per unit	Energy savings
Kitchen	3	Electric	95%	1	223.1 kWh
Bath	2	Electric	95%	1.17	127.1 kWh
Kitchen	3	Gas	65%	1	11.1 therms
Bath	2	Gas	65%	1.17	6.3 therms

As in the previous calculation, the average water use per faucet per person is a critical number in this calculation. The US EPA Water Conservation Plan Guidelines suggests 0.5 to 5 minutes/day/person for the kitchen faucet and 0.5 to 3 minutes/day/person for the bathroom faucet. The AWWA study found approximately 11 gallons/person/day of total faucet use (or 5 minutes at a 2.2 gpm flow rate). For our calculation, the 5 minutes/day/person predicted by the AWWA study was divided into water usages of 3 minutes/day/person for kitchen faucets and 2 minutes/day/person for bathroom faucets.

Patrick has not located any data on the portion of this water usage that is "hot" water, but it can be assumed that a portion of this water would be cold for drinking, rinsing or garbage disposal purposes, and a portion would be warm for washing. For this calculation, it is estimated that the average temperature will be the same as for showers—105°F.

Recommendations for further study: It is recommended that field installers perform random sample measurements of the flow rates from existing fixtures to better establish a baseline. Local data on water use habits both before and after retrofitting would enable an improved calculation by reducing uncertainties in the assumptions. Logging flow meters could be installed on a sample number of water heaters or individual fixtures to establish average hot water usage. A closer examination of census or RECS data could allow the development of a Wisconsin average for the number of fixtures/unit to replace the national average.

2. WHOLE BUILDING EXISTING, WHOLE BUILDING PROGRAM

Under the ACES Whole Building Program, multi-family residential building owners can receive rebates for voluntarily installing approved energy conservation measures to buildings' common areas and systems.

For each measure incentivized through the program, we first summarize the current default savings being used, our recommendations for changes to the current default savings, and a general discussion of prior studies and other assumptions used when evaluating the current default savings. This is followed by our recommendations for further study to strengthen the current or recommended default savings estimate.

2.1 PRESCRIPTIVE-CFL, COLD CATHODE OR LED LAMP REPLACEMENTS

This ACES deemed savings category includes CFL replacements in common area applications (hallways, stairwells, lobbies, utility rooms, exterior lighting, etc.) that would typically operate more than 4 hours a day—many for 24 hrs/day. It would also include the replacement of conventional exit signs with low-energy fluorescent, LED, or photo-luminescent exit signs; the replacement of conventional fluorescents with high-efficiency/lower-wattage equivalents; and fixture replacements.

Current default savings: The current value in use by ACES is 215 kWh/year/lamp in energy savings, and these savings are not differentiated among the lighting types. This annual energy savings would correspond to an average savings of 24.5 watts/lamp operating 24 hours/day, 36.8 watts/lamp operating 16 hours/day, or 49 watts/lamp operating 12 hours/day. ACES also estimates the peak demand load reduction as 47 watts/lamp.

Recommendation for change in deemed savings: For direct replacement of incandescents with CFLs in common areas, it is recommended that the default deemed savings value be increased to 407 kWh/year and that the default peak demand load reduction be reduced to 41.5 watts/lamp.

For replacement of incandescent or standard fluorescent exit signs with LED or other low-energy types, it is recommended that the deemed savings be 272 kWh/yr and the peak demand load savings be 31 watts/fixture.

For all other retrofits, it is recommended that the savings be calculated based on the actual reduction in watts achieved per fixture (DW) and either 12 or 24 hrs/day operation depending on whether the application was daylight controlled. The deemed savings would be either 4.38 x DW (kWh/yr) or 8.76 x DW (kWh/yr) accordingly. The peak load demand reduction would be either zero or DW.

Analysis and references: The wide variety of possible lighting system retrofits makes the determination of an average wattage savings highly uncertain. An average energy savings per lamp replacement can be easily calculated if one knows the wattage saved by the retrofit lamp or replacement fixture and the relative number of each type. However, since data on the distribution of types of lighting replacements was not readily available, we have divided the universe of possibilities into the following three categories: (1) direct replacement of incandescents with CFLs, (2) the replacement of incandescent and fluorescent exit signs with

LED or electroluminescent signs, and (3) other—to include linear fluorescent upgrades and fixture replacements.

2.1.1 Direct replacement of incandescents with CFLs:

The Pacific Gas and Electric Company's (PG&E) Compact Fluorescent Lamp Program For Multi-Unit Dwelling Customers (MUD)[12] reports the following results for CFLs in common area lighting applications.

Table 2-1. PG&E CFL Program for Multi-Unit Dwelling Customers Results

CFL Wattage	Incandescents replaced	Average watts saved	# installed
15W	40W and 60W in equal numbers	35	46,235
20W	60W and 75W in equal numbers	47.5	19,352
23W	75W and 100W in equal numbers	64.5	13,525
26W	100W	74	8,830
		Total	**87,942**
Weighted Average Watts Saved: 46.2 watts			

PG&E's assumptions included consumers using CFL replacement as an opportunity to improve light levels while still reducing electrical consumption. These assumptions result in reduced savings compared to the average 51.9 watts/lamp savings used for ACES installations under the direct install program. The MUD results do not include other types of lamp replacements, such as LED exit signs. Until similar data on the installation of CFLs by wattage under the ACES program is available to enable a refined, weighted average to be calculated, it is recommended that 51.9 watts/lamp continue to be used for calculating the deemed energy savings for direct replacement of incandescents.

It can be assumed that interior lighting (hallways, stairs, exit signs, etc.) would typically operate 24 hours/day and exterior lighting would operate an average of 12 hours/day. The PG&E report found that two-thirds of the replaced lights were exterior and one-third was interior. However, in Wisconsin's colder climate, using CFLs outdoors is more problematic. Preliminary data on ACES installations, from July 1, 2007, to April 29, 2008, where interior vs. exterior applications were noted, indicated that less than 20 percent of the CFL installations are outdoors. Assuming 20 percent exterior operation at 12 hrs/day and 80 percent interior operation at 24 hrs/day would result in an average operating time of 21.6 hours.

Using 51.9 watts/lamp as the average savings and lamps operating an average 21.6 hrs/day, this would result in an annual energy savings of 409 kWh/yr.

ACES also estimates the peak demand load reduction resulting from common area lighting retrofit installations as 47 watts/lamp. With the calculations and assumptions given here, if 80% of the lamps operate 24 hours/day, the equivalent peak demand load reduction would be

---

[12] Pacific Gas and Electric Company. *Subcompact Fluorescent Lamp Program for Multi-Unit Dwelling Customers.* PNL-SA-36714. June 17, 2002.

41.5 watts/lamp, not 47 watts/lamp as currently assumed. The other 20 percent of the lamps (exterior lighting) would likely be off during the peak period.

It is recommended that the default peak demand load reduction for CFLs be reduced to 41.5 watts/lamp.

2.1.2 The replacement of incandescent and fluorescent exit signs with LED or electroluminescent signs:

The ENERGY STAR calculator for exit signs uses an average default value of 36 watts/sign for conventional exit signs and 5 watts/sign for newer LED style signs (apparently the most popular and cost effective type). This results in a savings of 31 watts/sign and 272 kWh/year operating at 24 hours/day. The peak demand load reduction would also be 31 watts/sign.

2.1.3 Other retrofits—to include linear fluorescent upgrades, such as standard 2-foot and 4-foot lamps and ballasts, and fixture replacements.

The wide variety of possible upgrades in this category and the lack of statistics on the upgrades typically installed in multi-family, common area applications make determining an average savings with any degree of certainty very problematic. We recommend that the actual wattage reduction achieved (DW) be used to calculate the energy savings as follows.

Table 2-2. For a Given Wattage Reduction per Fixture (DW)

Application	Assumed Operating Hours	Annual Energy Savings (kWh/yr)	Peak load Demand Reduction (Watts)
Outdoor and indoor lights controlled by timers or daylight sensors	12 hrs/day	DW x 12 x 365 /1000 or 4.38 x DW	0
All other common area applications	24 hrs/day	DW x 24 x 365 /1000 or 8.76 x DW	DW

Recommendations for further study: The uncertainty in the average watts saved per lamp could be reduced with better field data on the relative numbers of lamp types replaced and their characteristic applications and operating hours in apartment and condominium applications in Wisconsin. In particular, the relative numbers of interior and exterior applications for CFLs found by the PG&E study in California seem counterintuitive for Wisconsin as shown by the preliminary Focus data, and this number should probably be revisited. It is suggested that the form be modified to include the number of lamps installed indoors and outdoors (or alternatively whether the installation is on a timer or a daylight or occupancy sensor control).

2.2 90%+ EFFICIENCY MODULATING BOILER REPLACEMENTS

Current default savings: The default deemed savings for boiler replacements used by ACES is 98 therms per year. The value is equal to the savings calculated for furnace replacements in single-family homes by the residential program.

Recommendation for change in deemed savings: Calculation of a single deemed savings value for multi-family building boiler replacements would be highly uncertain without good statistical data on the sizes of boilers being installed. It is recommended to use a Deemed Savings Multiplier (DSM) to convert the installed boiler capacity to a deemed savings. The recommended DSMs for the eleven zones defined by the Wisconsin Department of Administration, Division of Energy are listed in Table 2-3.

Table 2-3. Recommended Deemed Savings Multiplier for Boiler Replacements by Zones

DOA zone	DSM
1	**3.28**
2	**3.26**
3	**3.24**
4	**3.03**
5	**3.23**
6	**3.22**
7	**3.11**
8	**3.15**
9	**3.12**
10	**3.03**
11	**3.06**
WI Average (Population Weighted)	**3.11**

The deemed savings in therms/yr are calculated by multiplying the appropriate DSM times the installed boiler capacity in MBTUH. For example, a qualified, 300,000 BTUH (or 300 MBTUH), high efficiency boiler installed in Zone 9 would result in 300 MBTUH x 3.12 = 936 therms/yr deemed savings.

Analysis and references: The calculation of energy savings from the replacement of old boilers with new, more efficient boilers is governed by the following formulas[13]:

$$\Delta T = T_{indoor} - T_{out,design}$$

$$DHR = BC \times 0.77$$

$$\mathrm{DS} = DHR \times \left[\left(\frac{\mathrm{HDD} \times 24}{\Delta T} \right) \times (1/\eta_e - 1/\eta_p)/100 \right]$$

or

$$\mathrm{DS} = BC \times \left[0.77 \times \left(\frac{\mathrm{HDD} \times 24}{\Delta T} \right) \times (1/\eta_e - 1/\eta_p)/100 \right] = BC \times [DSM]$$

[13] The formula given uses a conventional, convenient approximation for a building's heating load (from *ASHRAE Fundamentals.* Pg. 28.3. 1989.), which assumes the load is proportional only to the outside temperature. It does not take into account changes in load due to increased infiltration or solar gain due to other weather factors or operating practices.

where,

T_{indoor} = desired indoor temperature at winter design conditions (ºF)
$T_{out,design}$ = outside winter design temperature (ºF)
DS = deemed savings (therms saved per year)
DHR = Design Heating Requirement (in MBTUH, where 1 MBTUH = 1,000 BTU)
BC = Boiler Capacity rating
0.77 = estimated average boiler oversizing.
η_p = proposed Annual Fuel Utilization Efficiency (AFUE)
η_e = standard AFUE
24 = Hours/day
HDD = Heating Degree-Days, base 65ºF
100 = Conversion factor from MBTU to therms
DSM = Deemed Savings Multiplier,

The indoor temperature (T_{indoor}) in engineering calculations is typically 65ºF. This is chosen instead of higher temperatures to allow for internal heat gains from lights, appliances and human activity, and coincides with the value used to calculate heating degree-days.

Average values for the outside design temperature ($T_{out,design}$) and for heating degree days (HDD), are defined for eleven zones in Wisconsin by the Administrative Code[14] and the Division of Energy[15]:

Table 2-4. Average Outside Design Temperature by Zone

DOA zone	Heating Degree-Days[14] (base 65ºF)	Outside Design Temp[15] (ºF)
1	9,150	-25
2	9,080	-25
3	8,528	-20
4	8,452	-25
5	8,493	-20
6	7,976	-15
7	8,196	-20
8	8,282	-20
9	7,730	-15
10	7,499	-15
11	7,096	-10
WI Average (Pop. Weighted)	**7,699**	**-15**

The deemed energy savings (DS) are calculated as the difference between the annual energy consumption of a conventional, standard efficiency replacement boiler and a modulating,

[14] Wisconsin Department of Administration. *2005 Wisconsin Energy Statistics.* 2005.

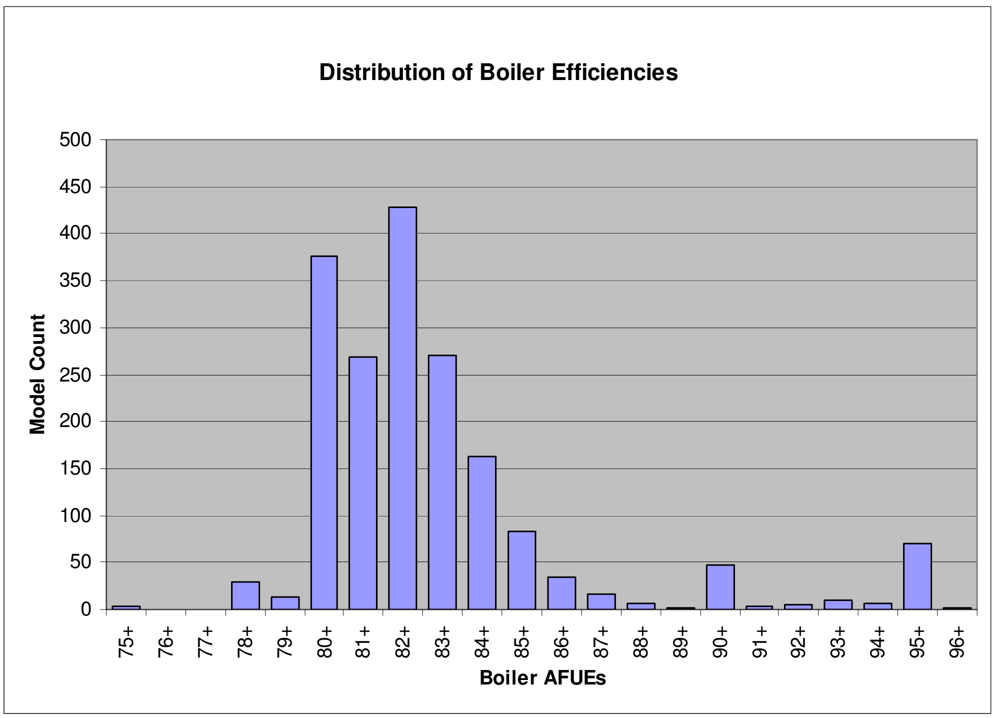
[15] "Wisconsin Administrative Code". 2004 Chapter 63.1023. Figure 63.1023.

condensing boiler. The annual energy consumption of a standard efficiency boiler is used instead of the actual efficiency of the old boiler because (1) a non-operational boiler would be replaced (at minimum) by a standard efficiency boiler, and (2) determining an average efficiency of the boilers being replaced would introduce large uncertainties.

The standard boiler efficiency, η_e, is recommended to be 80% based on the level required by code (IECC 2006). The proposed boiler efficiency, η_p, is chosen to be 93% based on an analysis completed by Patrick examining the market availability of boilers of various efficiencies.

The 1835 boiler models listed in the latest GAMA directory[16] were sorted by AFUE ratings and tallied. The distribution of boiler models by AFUE is illustrated in Figure 2-1.

Figure 2-1. Distribution of Boiler Efficiencies



The average AFUE of all boilers was 83.3%; the median AFUE of all boilers was 82.2%; the average efficiency of boilers with AFUEs less than 90% was 82.2%; and the median of boilers with AFUEs less than 90% was 82%. The average and median of efficiency of boilers with AFUEs greater than 90% was 93.2%. A rounded value of 93% was chosen as a good, conservative estimate of the efficiency of a boiler installed under this measure.

However, the distribution of boiler model efficiencies does not adequately represent the market share of each model. If significant numbers of the slightly more efficient (82+%) are

---

[16] Gas Appliance Manufacturers Association. *Consumer's Directory of Certified Efficiency Ratings.* Arlington, VA. March 31, 2008.

sold rather than the less expensive 80+% boilers that just meet code, the baseline representing standard practice could be higher than 80%. An adjustment for a possibly higher baseline will be incorporated into the net-to-gross calculation.

The building design heating requirement (*DHR*) is the maximum building heat loss at the design temperature and is dependent on a number of variables including building size, insulation levels, infiltration, and fenestration. It is usually determined by a knowledgeable architect or contractor. However, to cover uncertainties in the actual load requirements, it is standard practice to oversize boilers by 20 to 30 percent. Cautious designers have often oversized boilers as much as 50 percent, but sometimes two to three times the required heating capacity. The practice of oversizing boilers can decrease the efficiency and operating life of a boiler because of short cycling (frequent on-off cycles). Modulating boilers can partially compensate for oversizing, but a properly sized, modulating boiler will still be more efficient. For the purpose of these calculations, we have assumed that at the *DHR* can be approximated by 77 percent of the new boiler capacity (*BC*).

Since good, statistical data on the average *DHR* or the average boiler capacity for ACES installations is not available, we are proposing to combine the input variables discussed above (those within the square brackets of the formula for deemed savings) into a single multiplier which we designate as the DSM or the Deemed Savings Multiplier. This number multiplied by the boiler capacity in MBTUH will calculate the deemed savings in therms/yr for an installation in a given zone. The results of these calculations are provided in Table 2-3 above.

Recommendations for further study: Additional data on the efficiencies of the boilers typically installed ***without*** the ACES incentives would enable a more accurate estimate of the baseline AFUE. A survey of heating contractors could better define the standard practice baseline.

Such a survey of heating contractors could also help determine how much boilers are typically oversized relative to the building design heating requirement and allow the DSM adjustment for that factor to be better defined, if necessary.

3. NEW CONSTRUCTION PROGRAM

Focus on Energy offers incentives to apartment and condominium developers that plan for and implement energy efficiency into their new buildings.

For each measure installed through the program, we first summarize the current default savings being used, our recommendations for changes to the current default savings, and a general discussion of prior studies and other assumptions used when evaluating the current default savings. This is followed by our recommendations for further study to strengthen the current/recommended default savings estimate.

3.1 90%+ EFFICIENCY MODULATING BOILER INSTALLATIONS

Current default savings: No default deemed savings for new boiler installations have been established by ACES. The database indicates that individual, custom energy savings calculations have been used in past years for new boiler installations.

Recommendation for change in deemed savings: In lieu of individual, verified calculations of energy efficiency improvements above the minimums required by IECC 2006, it is recommended that the default deemed savings be calculated using the same deemed savings multipliers (DSM) proposed for the Whole Building Existing Program.

Analysis and references: Same as 90%+ Efficiency Modulating Boiler Installations under the Whole Building Existing Program.

Recommendations for further study: Same as 90%+ Efficiency Modulating Boiler Installations under the Whole Building Existing Program.

3.2 COMMON AREA LIGHTING

Current default savings: No default deemed savings for new construction common area lighting has been established by ACES. The database indicates that individual, custom energy savings calculations have been used in past years for common area lighting installations.

Recommendation for change in deemed savings: It is recommended that the energy savings and incentives for individual systems should be individually calculated based on the installed lighting system performance and the energy saved relative to the maximum wattage allowed by the IECC 2006 performance specifications. No default deemed savings should be established for common area lighting systems installed in new construction

Analysis and references: The newly adopted (March 2008) baseline for energy conservation calculations for new construction is the International Energy Conservation Code 2006. For common area lighting systems, these standards are expressed as a performance standard rather than a prescriptive one. The standards set maximum limits on the power used for lighting in terms of watts per square foot or watts per linear foot depending on the application. While some of the standards could conceivably be met by incandescent lamps, many could not be met, while maintaining adequate illumination, without using more energy efficient lighting in the system design.

For example, IEEC 2006 limits lighting in multi-family interior building areas to 0.7 Watts/ft^2. For a 6-foot by 40-foot hallway, the Code would allow up to 168 watts to illuminate that hallway. If the hallway is lighted with four 30W fluorescent fixtures, the savings would be:

168W [Code Maximum] – (4 x 30W) [Installed] = 48W [or 12W/fixture]

Assuming 24 hrs/day operation, the annual savings would be 105 kWh/fixture.

The 2007 Focus baseline review report[17] recommended that the program "*focus on non-lighting areas for efficiency as the new, lower code levels for lighting power density will make it increasingly difficult to gain past percentages of savings, and there will be push-back from electrical engineers/contractors and lighting designers on further lowering W/ft2 levels and fixture counts."* However, as the example calculation above demonstrates, some additional savings are still available.

The possible solutions to any lighting system design are many and varied and dependent on considerations other than energy consumption, such as aesthetics and required illumination levels. Making a determination of an average, deemed savings for new construction would involve far too many uncertainties.

Recommendations for further study: A survey of new lighting systems being installed and a review of incentive applications received after the new code adoption should provide evidence of the specific additional energy savings possible and practicable in common area lighting systems under the new code.

[17] Energy Center of Wisconsin, *Market Review and Interim Baseline for the 2007 Focus on Energy New Construction Program,* May 2007