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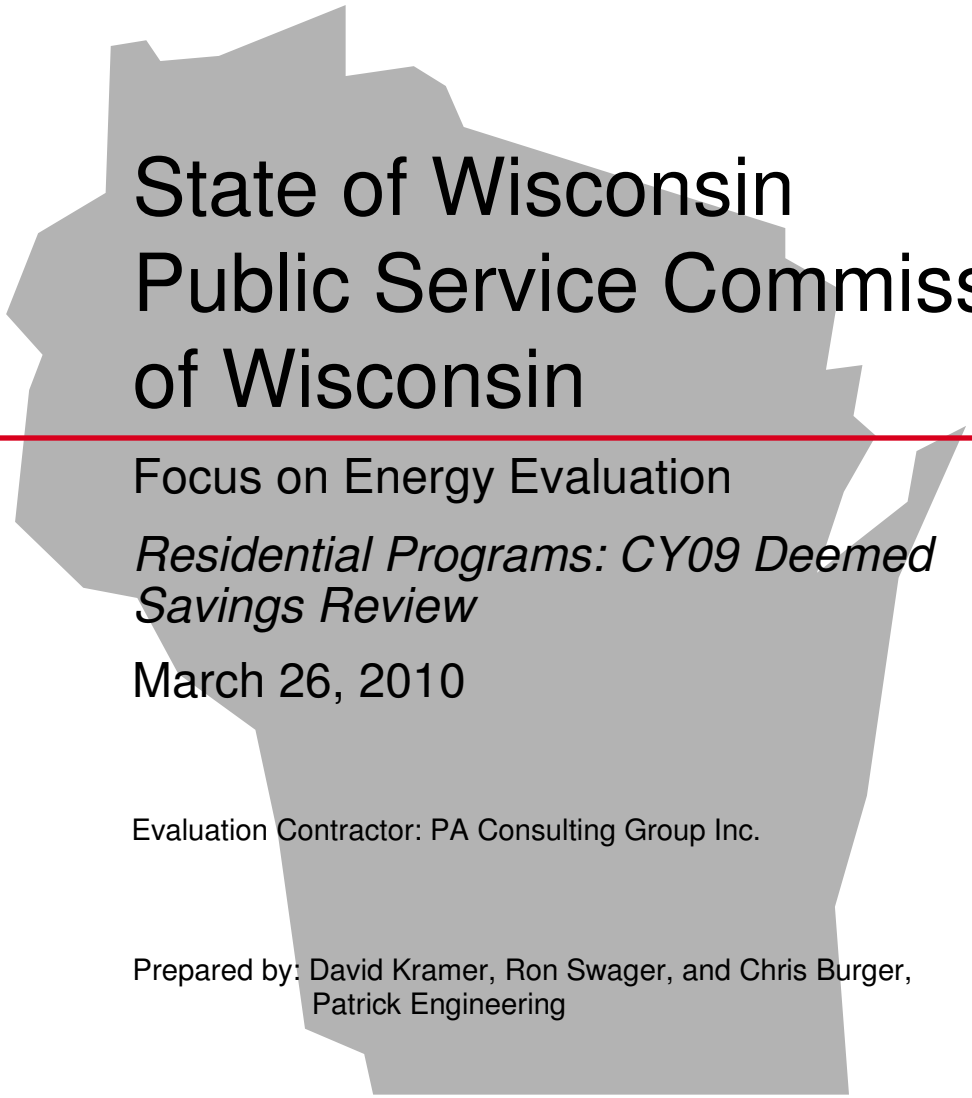

State of Wisconsin Public Service Commission of Wisconsin

Focus on Energy Evaluation

Residential Programs: CY09 Deemed Savings Review

March 26, 2010

Evaluation Contractor: PA Consulting Group Inc.

Prepared by: David Kramer, Ron Swager, and Chris Burger,
Patrick Engineering

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The power is within you.

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1. INTRODUCTION

This report focuses on the deemed savings for the following measures:

- Boiler tune and clean
- Split air conditioners
- Electric hot water heaters.

The boiler tune and clean and the split air conditioners were specified as needing review by the evaluation team and identified as a task in the ACES section of the CY09 detailed evaluation plans[1].

On November 2, 2009, Sara Van de Grift of Wisconsin Energy Conservation Corporation (WECC) submitted to David Sumi of PA Consulting Group a memo entitled *Residential Programs – Deemed Savings Review of the Condensing Water Heater and the Indirect Water Heater.* The memo requested a review of the current deemed savings for the following:

- Condensing water heater (tank and tankless)
- Indirect water heater (installed with a high efficiency hot-water boiler)
- ECM furnace new construction
- Targeted Home Performance with ENERGY STAR® whole house therm savings.

This document presents the evaluation team's recommendations, based upon detailed review, for maintaining or changing the deemed savings values for each of the aforementioned measures. For each measure where the deemed savings values and assumptions were reviewed, we summarize the current default savings used, share our recommendations for changes to the current default savings, and provide 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 estimates.

In almost all cases, these recommendations require fieldwork to obtain the measurements of variables that are critical inputs to the deemed savings calculations. There are often significant costs associated with obtaining these measurements, so decisions must be made about whether the increased accuracy in the deemed values is worth the additional fieldwork costs and about whether the measurements should be the responsibility of the program administrator or the evaluator.

[1] Focus on Energy Evaluation Team, *Focus on Energy Evaluation, Evaluation Calendar Year 2009, Detailed Evaluation Plans,* Final: April 21, 2009.

2. BOILER TUNE AND CLEAN

Current default savings. The default database savings value appears to be 0.0011 therms per an unidentified unit. No back-up reference was supplied or found.

Recommendation for change in deemed savings. The calculation of a single deemed savings value for multi-family building boiler tuning would be highly uncertain without good statistical data on the sizes of the maintained boilers. The calculation below shows increasing the efficiency from 80 to 81 percent would save 33.5 therms per 100,000 Btu per hour of boiler size.

Analysis and references. We recommend using a deemed savings multiplier (DSM) to convert the installed boiler capacity to a deemed savings.

The deemed savings, in therms per year, are calculated by multiplying the installed boiler capacity in MBtu per hour by the DSM based on efficiency improvement.

The calculation of energy savings from the maintenance of the boilers governed by the following formulas[2]:

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

$$DHR = BC \times 1.0$$

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

or

$$\mathrm{DS} = BC \times \left[1.0 \times \left(\frac{\mathrm{HDD} \times 24}{\Delta T} \right) \times (1/\eta_e - 1/\eta_p)/100 \right] \qquad = BC \times [DSM\ ]$$

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 MBtu per hour, where 1 MBtu per hour = 1,000 Btu)
BC	=	Boiler Capacity rating
1.0	=	estimated average boiler oversizing (assumes none).
η_p	=	proposed new Annual Fuel Utilization Efficiency (AFUE) after cleaning
η_e	=	standard AFUE before cleaning
24	=	Hours per day
HDD	=	Heating Degree-Days, base 65 degrees (ºF)

[2] 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.

100 = Conversion factor from MBtu to therms
DSM = Deemed Savings Multiplier,

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

Average values for the outside design temperature ($T_{out,design}$) and for HDD, are defined for eleven zones in Wisconsin by the Administrative Code[3] and the Division of Energy[4].

Table 2-1. Average Outside Design Temperature by Zone

DOA zone	Heating Degree Days (base 65º F)	Outside Design Temp[5] (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 the boiler before and after cleaning.

The standard boiler efficiency, η_e, is recommended to be 80 percent based on the level required by code (IECC 2006). The proposed boiler efficiency, $\eta_{p,}$ is chosen to be 81 percent to demonstrate what a one percent efficiency increase will accomplish. Use 100,000 Btu per hour as the boiler size to provide an easy multiplication factor and the average HDD and design temperature from Table 2-1.

DSM = 100,000 × ((7,699 × 24)/(70-(-15)) × (((1/80)-(1/81))/100) = 33.5 therms per year per one percent efficiency increase per 100,000 Btu per hour of boiler size.

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

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

Boiler efficiency will be affected by burner type, boiler age, fuel burned, water treatment of the heating hot water, location in the state, and oversize ratio.

Recommendations for further study. Contractors could do a combustion analysis test and test return water temps and exhaust to find efficiency measure the change in efficiency resulting from a boiler tune and clean. However, it is recognized that not all contractors have the equipment to do this test. Also, there is additional time required to take these measurements. Therefore, it is impractical to require these measurements be taken for all implementations. If it is determined, however, that this is going to continue to be an offering in the ACES program, it may be worthwhile to conduct a joint research effort between WECC and the evaluation team to take measurements from a sample of projects are they are being implemented in the field.

3. SPLIT AIR CONDITIONERS

Current default savings. ACES currently uses the numbers presented in Table 3-1 as the default savings value for split air conditioner upgrades in both new and existing construction. The comparable numbers for the Efficient Heating & Cooling (EHCI) program are also shown in Table 3-1. We were not provided any information regarding how these numbers were derived.

Table 3-1. Present Deemed Savings

	ACES		EHCI	
SEER	kW Reduction	kWh Reduction	kW Reduction	kWh Reduction
14	0.20	82	0.1	54
15	0.37	154	0.17	101
16	0.52	216	0.28	142

Recommendation for change in deemed savings for Residences. We recommend that the default deemed savings currently used by for the EHC program in Table 3-1, be used for all residential installations of split air conditioners. These adjustments reflect the baseline assumptions of a 13 Seasonal Energy Efficiency Ratio (SEER) rating and the full-load hours (FLH) justified in the May 2008 Energy Center of Wisconsin (ECW) study on central air conditioning in Wisconsin[6].

Analysis and references. For this calculation, we adapted a sample calculation with the indicated assumptions illustrated below.

$$\text{kW Savings} = \text{Size} \times (((1/SEER_{13}) - (1/SEER_{proposed})) \times C)$$

$$\text{kWh} = \text{Size} \times FLH/(SEER \times C)$$

$$\text{kWh Savings} = kWh_{SEER13} - kWh_{SEERproposed}$$

Where: Size = Air Conditioner size in Btu per hour

$SEER_{13}$ = 13 Btu per watt

$SEER_{proposed}$ = 14, 15 or 16 Btu per watt

C = 1000W per kW

FLH = Operating Hours = 311 hours per year

[6] Scott Pigg, Energy Center of Wisconsin. *Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research.* May 2008.

Table 3-2 presents air conditioner size information from past studies in Wisconsin.

Table 3-2. Wisconsin Air Conditioner Size Data

Size (tons)	Studies			
	1999	STAC 2005	Focus 2007	Average
1.5	6	3	9	6
2.0	41	57	33	41
2.5	24	22	33	26
3.0	23	19	20	22
3.5	4	0	1	3
4.0	2	0	3	2
5.0	1	0	1	1
Prorated size (tons)	2.470	2.305	2.425	2.455

The following kW and kWh data, for units having a SEER rating of 14, 15, or 16, were calculated for the prorated size of 2.425 tons, used in the Focus 2007 study, versus a SEER 13 unit. The SEER 13 unit was used as the baseline since this is the required rating per Federal guidelines.

Table 3-3. Annual Savings

SEER	kW Reduction	kWh Savings
14	0.16	50
15	0.30	93
16	0.42	131

The kW reduction calculated in Table 3-3 is higher than the EHCI numbers, but the kWh savings are slightly less than the EHCI numbers. The numbers for both are less than the ACES deemed numbers. The base from which the ACES numbers were calculated was not available and either the FLH or existing unit size could account for the difference.

Recommendations for further study. If it is determined that it is worthwhile to apply resources to reduce uncertainty in the deemed values for this measure, we would recommend a joint research effort between the program administrator and evaluation. Some number of these projects would be randomly selected for metering prior to installation of the measure. The contractor would install the meter at the time of the installation. The evaluators would collect the meters at the end of the season and conduct the analysis to determine gather empirical data on the actual operating hours of the equipment.

4. ELECTRIC HOT WATER HEATERS

Current default savings. The current ACES default deemed savings for the installation of electric hot water heater conversion are shown in the Table 4-1.

Table 4-1. Default Deemed Savings for Electric Hot Water Heater Conversion

Application	Annual Default Energy Savings (kWh)
Fuel conversion electric-gas	3,280
Conversion to 93%+ electric	260

This analysis was based on the assumption of 45 gallons per day of usage per unit, a 75-degree (ºF) temperature rise and a greater than or equal to 80 percent natural gas replacement unit to derive these figures. The conversion to greater than or equal to 93 percent electric appears to be based on a 75-gallon existing unit that complies with IECC 2006 requirements, the same 45-gallon per day usage, and the 75-degree temperature rise.

Recommendation for change in deemed savings. We recommend that the default values be adjusted as shown in Table 4-2.

Table 4-2. Recommended Changes to Default Deemed Savings for Electric Hot Water Heater Conversion

Application	Annual Default Energy Savings (kWh)
Fuel conversion electric-gas	2,624
Conversion to 93%+ electric	208

Analysis and references. For this calculation, we assumed the temperature rise was 60 degrees instead of 75 degrees. Hot water is used for washing and bathing at about 105 degrees not 125 degrees as the 75-degree rise would indicate. All the other assumptions remained unchanged.

The 60-degree temperature rise is based on a groundwater temperature of 47 degrees for Wisconsin based on typical mean groundwater temperature figure from geothermal heat pumps systems and a water usage temperature of 106.4 degrees from the BPA Energy Efficient Showerhead study[7].

The fuel conversion would increase natural gas usage dependent on the efficiency of the unit installed. The current default number is 143 therms which would be reduced by the ratio of the temperature rise or 55 degrees over 75 degrees to 105 therms. The present therms increase appears to be based on an 80 percent efficient unit of 75-gallon size.

In the calculation, the average water use per unit, the water heater size and temperature rise are critical numbers in this calculation.

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[7] SBW Consulting, Inc. *Energy Efficient Showerhead and Faucet Aerator Metering Study Multifamily Residences: A Measurement and Evaluation Report.* http://www.bpa.gov/energy/n/Reports/evaluation/residential/faucet_aerator.cfm. October 1994.

Recommendations for further study. We recommend a joint research effort between the program administrator and the evaluators to capture random sample measurements of the hot water usage to better establish a baseline. Local data on water heater temperature settings and the temperature water is used would enable an improved calculation by reducing uncertainties in the assumptions. In addition, inlet water temperature to the water heater should be measured. Logging flow meters could be installed on a sample number of water heaters to establish average hot water usage.

5. CONDENSING WATER HEATERS

This ACES deemed savings category includes replacement of existing natural gas fired water heaters with condensing hot water heaters with a thermal efficiency of greater than or equal to 90 percent.

Current default savings. The current value in use is 85 therms per year in energy savings based on WECC calculations.

Recommendation for change in deemed savings for ACES & EHC. The deemed savings should be reduced to 32 therms per year.

Analysis and references. The existing deemed savings are assumed to be based on the 45-gallons per day usage per unit, a 75-degree (ºF) temperature rise, and a present thermal efficiency of 0.67 based on IECC 2006 standards. The proposed deemed savings are based on the 45-gallons per day usage per unit, a 60-degree temperature rise (See Page 4-1), and a present thermal efficiency of 0.67 based on IECC 2006 standards versus a new thermal efficiency of 0.90.

Energy Usage = gpd × C × C2 ×* Temperature Rise × Days/year/(thermal efficiency × K)

Where: gpd = 45 gallons per day
C = 8.33 pounds per gallon
C2 = 1.0 Btu per pound per degree (ºF)
Temperature Rise = 75 degrees existing, 55 degrees proposed
Days/Years = 365 days per year
Thermal Efficiency = 0.67 existing and 0.90 proposed
And K = 100,000 Btu per therm

$\text{Energy Use}_{existing}$ = 45 × 8.33 × 1 × 75 × 365/(0.67 × 100,000) = 153 therms

$\text{Energy Use}_{proposed}$ = 45 × 8.33 × 1 × 75 × 365/(0.90 × 100,000) = 114 therms

$\text{Energy Use}_{existing}$ = 45 × 8.33 × 1 × 60 × 365/(0.67 × 100,000) = 123 therms

$\text{Energy Use}_{proposed}$ = 45 × 8.33 × 1 × 60 × 365/(0.90 × 100,000) = 91 therms

If 75 degrees; savings is 153 - 114 = 39 therms

If 55 degrees; savings is 123 – 91 = 32 therms

Recommendations for further study. We recommend a joint research effort between the program administrator and the evaluators to capture random sample measurements of the hot water usage to better establish a baseline. Local data on water heater temperature settings and the temperature water is used would enable an improved calculation by reducing uncertainties in the assumptions. In addition, inlet water temperature to the water heater should be measured. Logging flow meters could be installed on a sample number of water heaters to establish average hot water usage.

6. INDIRECT WATER HEATERS

Current default savings. Based on WECC calculations, the current value in use is 85 therms per year in energy savings.

Recommendation for change in deemed savings for ACES & EHC. The deemed savings should be reduced to 32 therms per year.

Analysis and references. The existing deemed savings are assumed to be based on the 45-gallons per day usage per unit, a 75-degree (ºF) temperature rise, and a present thermal efficiency of 0.67 based on IECC 2006 standards. The proposed deemed savings are based on the 45-gallons per day usage per unit, a 60-degree temperature rise, and a present thermal efficiency of 0.67 based on IECC 2006 standards versus a new thermal efficiency of 0.90 for the boiler system.

The numbers assume the tank size is the same in both situations so no storage losses are saved. The water heater also has an energy source to heat the water if the boiler is shut off during the non-heating seasons.

Energy Usage = gpd × C × C2 × Temperature Rise × Days/year/(thermal efficiency × K)

Where: gpd = 45 gallons per day
C = 8.33 pounds per gallon
C2 = 1.0 Btu per pound per degree (ºF)
Temperature Rise = 75 degrees existing, 60 degrees proposed
Days/Years = 365 days per year
Thermal Efficiency = 0.67 existing and 0.90 proposed
And K = 100,000 Btu per therm

$\text{Energy Use}_{existing}$ = 45 × 8.33 × 1 × 75 × 365/(0.67 × 100,000) = 153 therms

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$\text{Energy Use}_{existing}$ = 45 × 8.33 × 1 × 60 × 365/(0.67 × 100,000) = 123 therms

$\text{Energy Use}_{proposed}$ = 45 × 8.33 × 1 × 60 × 365/(0.90 × 100,000) = 91 therms

If 75 degrees; savings is 153 - 114 = 39 therms

If 55 degrees; savings is 123 – 91 = 32 therms

Recommendations for further study We recommend a joint research effort between the program administrator and the evaluators to capture random sample measurements of the hot water usage to better establish a baseline. Local data on water heater temperature settings and the temperature water is used would enable an improved calculation by reducing uncertainties in the assumptions. In addition, inlet water temperature to the water heater should be measured. Logging flow meters could be installed on a sample number of water heaters to establish average hot water usage.

7. ECM FURNACE

Current default savings. Current default deemed savings for electronically commutated motor (ECM) furnace installations in new construction with ECM motors are 0.17 kW, 1,116 kWh per year and 20 therms per year.[8] Review of these numbers indicates that the present savings are based on a CAC operational period of 400 hours a year.

Recommendation for change in deemed savings. We recommend changing the annual kWh savings to 1,079 kWh per year, but leaving the kW and therms per year unchanged. Table 10 of the 2009 Focus residential deemed savings report[9] and Table 6-1 of the June 2004 ECM Furnace Impact report[10] use 1,126 as the kWh per year number using the control group as the baseline for the WESH program. This number is based on the CAC hours of 400 per year. Table 7 (hours of fans operation) in the 2009 report shows 310 hours as the annual operating time for CACs in new homes and a total annual time of 8,800 hours instead of 8,760 hours. Using the connected load values from Table 6 of the 2009 report shows a savings of 73 watts, plus 400 watts for the fan, indicates an annual reduction of 43.6 kWh (473 W/1000W/kW × 90 hours per year). The difference (of 1,126 kWh – 43.6 kWh) equals 1,083.4 kWh. This should be adjusted by the ration of 8,760 hours per year divided by 8,800 hours per year, which is 0.9955. Therefore, the annual deemed savings is: 1,083.4 × 0.9955 = 1,078.5 or 1,079 kWh per year. The peak kW draw of each unit is unchanged from the 2008 study and the kW is based on a calculated coincidental draw that would remain unchanged, since peak AC periods would remain unchanged since they are driven by climatic conditions.

Analysis and references. See the 2004 ECM furnace impact assessment[11], the 2008 ACES default deemed savings review[12], the 2009 ECM furnace impact assessment [13], and the 2009 residential deemed savings review[14].

Recommendations for further study. Additional data on the efficiencies of the furnaces and motors typically installed *without* the incentives would enable a more accurate estimate of the

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[8] Tom Talerico and Rick Winch, Glacier Consulting Group, LLC. *Residential Programs—Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report.* June 28, 2004. The 1,116 kWh/yr are presented on page 4-10. The summary Table 4-8 shows 1,126 kWh per year using the control group as the baseline on page 4-11.

[9] Ron Swager, Patrick Engineering, Inc. *Residential Deemed Savings Review.* February 2, 2009.

[10] Tom Talerico and Rick Winch, Glacier Consulting Group, LLC. *Residential Programs—Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report.* June 28, 2004.

[11] Ibid.

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

[13] Tom Talerico and Rick Winch, Glacier Consulting Group, LLC. *ECM Furnace Impact Assessment Report.* January 12, 2009.

[14] Ron Swager, Patrick Engineering, Inc. *Residential Deemed Savings Review.* February 2, 2009.

baseline annual fuel utilization efficiency (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 furnaces are typically oversized relative to the building design heating requirement and allow the DSM adjustment for that factor to be better defined, if necessary. It is recognized that smaller equipment tends to have longer run times. However, the objective of the survey is to determine the over-sizing to allow for adjustments of the numbers whether they increase or decrease, providing a more accurate deemed savings value.

8. WHOLE HOUSE THERM SAVINGS

Current default savings. With regards to the Targeted Home Performance with ENERGY STAR whole house therm savings, it was recommended in July 2009, that the program use the new deemed therm savings of 276 therms per house.[15]

Recommendation for change in deemed savings. As the above recommendation was submitted by the evaluation team, we still believe that this is the appropriate value. Therefore, we recommend no changes in deemed savings.

Analysis and references. No additional analyses are required, as we recommend that the adjusted deemed therm savings value remains as is.

Recommendations for further study. At this point in time, we do not feel that further study is required.

[15] Focus Evaluation Team. *Recommended Targeted Home Performance with ENERGY STAR Impacts Report.* June 28, 2009.