APPENDIX 7-B. HOT WATER DRAW MODEL

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APPENDIX 7-B. HOT WATER DRAW MODEL

7-B.1   INTRODUCTION

DOE developed a modified Hot Water Draw Model[1] as an improvement on a previously existing model. The Hot Water Draw Model estimates the average daily volume of hot water used by various households by accounting for the key characteristics described below.

DOE modified the Hot Water Draw Model to be able to calculate seasonal hot water use. DOE also adjusted the Hot Water Draw Model to account for changes in hot water use by clothes washers and dishwashers due to the updated Federal energy conservation standards for these products.

7-B.2   SEASONAL EFFECT ADJUSTMENTS

The seasonal coefficients for spring, summer, fall, and winter were derived using the linear regression results in the EPRI study found in appendix A of Modeling Patterns of Hot Water Use in Households.[1] Table 7-B.2.1 provides the detailed seasonal coefficients by hour. To obtain the total values, number of hours was multiplied by the coefficients.

Table 7-B.2.1   Summary of EPRI Analysis Results for Seasonal Coefficients

hour	# hours	Weekday (I-P units)				Weekend (I-P units)			
		a10	a11	a12	a13	a10	a11	a12	a13
		(spring)	(summer)	(fall)	(winter)	(spring)	(summer)	(fall)	(winter)
11-6	7	0	0	0	0.1459	0.0907	0.1675	0	0.1696
6-8	2	0	-3.593	0	0	0	-1.569	-0.6553	0
8-11	3	0	0	-0.432	0.5654	1.2574	0	0	1.3516
11-1	2	0	0	-0.4447	0.4012	0	-1.2638	0	1.4804
1-5	4	0	0	0	0.683	0	-0.9405	0	1.1756
5-7	2	0	-0.9736	0	0.9658	0	-1.4838	0	1.6384
7-9	2	0	-2.1273	-0.8588	0	0.8262	-0.9764	0	0
9-11	2	0	-0.8922	-0.9381	0	0	0	-0.3788	0
	Total	0	-15.1722	-5.7792	8.1835	6.0595	-13.1755	-2.0682	16.182

To obtain the daily average values (see Table 7-B.2.2) the coefficients were weighted by the number of days in the week which are weekend and weekday.

Table 7-B.2.2   Summary of Seasonal Values

Seasonal Coefficient	Average Value	Standard Deviation
Spring	1.731286	0.52
Summer	-14.6017	4.35
Fall	-4.71891	1.41
Winter	10.46879	3.12

7-B.3   CLOTHES WASHER AND DISHWASHER ADJUSTMENTS

The Hot Water Draw Model incorporates the parameters for clothes washer and dishwasher hot water use. These parameters reflect assumptions about clothes washer and dishwasher water use as they existed in the 1990s. Since that time, there has been a considerable change to clothes washer and dishwasher technology that has resulted in lower hot water use. In particular, updated Federal energy conservation standards for clothes washers that became effective in 2007[2] and for dishwashers that will become effective in 2010[3] have a significant impact on clothes washer and dishwasher hot water use.

The baseline water use for clothes washers in the 1990s was 39.2 gallons/cycle and the water use calculated based on the 2007 standard is 21.0 gallons/cycle.[2] The baseline water use for dishwashers in the 1990s was 8.2 gallons/cycle and the water use calculated based on the 2010 standard is 6.5 gallons/cycle.[4] Therefore, DOE updated the draw model to account for the reduced hot water use by adjusting the dishwasher and clothes washer water use variables to account for the new standards. The results are shown in Table 7-B.3.1. For example, the impact on gas-fired storage water heaters was a reduction of the average daily water use by 10.7 percent.

Table 7-B.3.1   Impact of Clothes Washer and Dishwasher Adjustments

Product Classes	Average Hot Water Use (not Adjusted)	Average Hot Water Use (Adjusted)	Change in Hot Water Use	Percent Change
	gal	Gal	gal	%
Gas-fired (Storage) Water Heater	50.7	45.3	-5.4	-10.7
Electric Water Heater	47.5	43.1	-4.4	-9.3
Oil-fired Water Heater	48.2	43.0	-5.2	-10.8
Gas (Instantaneous) Water Heater	51.3	46.4	-4.9	-9.6

7-B.4   HOT WATER DRAW MODEL COEFFICIENTS AND VARIABLES

The Hot Water Draw Model uses an equation that is expressed as follows:

$$
\begin{aligned}
vol = \{ & sea\_coef + (per\_coef \times per) + (age1\_coef \times age1) + (age2\_coef \times age2) + \\
& [age34\_coef \times (age3 + age4)] + (T_{tank}\_coef \times T_{tank}) + (Tanksz\_coef \times Tanksz) + \\
& (T_{in}\_coef \times T_{in}) + (T_{air}\_coef \times T_{air}) + (home\_coef \times athome) - \\
& [(0.692 \times per + 1.335 \times \sqrt{per}) \times dw\_adj] - [(1.1688 \times per + 4.7737 \times \sqrt{per}) \times cw\_adj] \} \times \\
& (senior\_mf\_coef \times senior\_mf) \times (no\_pay\_coef \times no\_pay)
\end{aligned}
$$

Table 7-B.4.1 lists the variables used in the equation as well as the definition and derivation of the value for each RECS household

Table 7-B.4.1   Variable Definition and Value Derivations

Variable	Definition	Value Derivation
per	total number of persons in household	=NHSLDMEM*
age1	number of preschool children, age 0-5 yrs	=PRESCHOOLCHILDREN**
age2	number of school age children, age 6-13 yrs	=SCHOOLCHILDREN**
age3	number of adults, age 14-64 yrs	=ADULTS**
age4	number of adults, age 65 yrs and over	=SENIORS**
T_{tank}	water heater thermostat setting, °F	Uniform distribution from contractor survey (See Ch. 7)
*Tank*sz	water heater nominal tank size, gal	Derived using WHEATSIZ and methodology described in Ch. 7
T_{in}	water heater inlet water temperature, °F	Calculated (See Ch.7)
T_{air}	outdoor air temperature, °F	Derived using HD65 and CD65 variables, using the methodology described in appendix 7-D
athome	presence of adults at home during day	=ATHOME*
dw_adj	adjustment factor to account for the differences due to the current energy conservation standard for dishwasher and for the cases of households with no dishwasher	= IF DISHWASH*=1 then .207 IF DISHWASH*≠1 then 1
cw_adj	adjustment factor to account for the differences due to the current energy conservation standard for cloth washers and for the cases of households with no cloth washers	= IF CWASHER*=1 then .464 IF CWASHER*≠1 then 1

senior_mf	senior-only household in a multi-family building	= IF TYPEHUQ*=4 or 5 AND
		   NHSLDMEM*=YEAR4*, then 1;
		= IF TYPEHUQ*≠4 or 5 OR
		   NHSLDMEM*≠YEAR4*, then 0

no_pay	household does not pay for hot water	= IF (PGASHTWA, LPGPAY, PELHOTWA, or FOPAY)*=1 then 0 = IF (PGASHTWA, LPGPAY, PELHOTWA, or FOPAY)*≠1 then 1

* RECS 2005 variable. See appendix 7-A for definitions.
** Values derived from RECS 2005 variables.

Table 7-B.4.2 lists the coefficients used in the equation as well as the definition and normal distribution parameters for each RECS household

Table 7-B.4.2   Coefficient Definitions

Coefficient	Definition	Normal Distribution Parameters	
		Average Value	Standard Deviation
sea_coef	coefficient for seasonal effects	See Table D.2.2	
per_coef	coefficient for total number of persons in household	0.974	0.09
age1_coef	coefficient for age1	6.393	0.71
age2_coef	coefficient for age2	10.518	0.63
age34_coef	coefficient for age3 + age4	15.305	0.67
home_coef	coefficient for athome	10.219	1.44
$Tank_{sz}\_coef$	coefficient for tank size	0.144	0.03
T_{tank}_coef	coefficient for water heater setpoint	-0.128	0.02
T_{inlet}_coef	coefficient for water heater inlet temperature	-0.179	0.05
T_{air}_coef	coefficient for average outdoor temperature	0.512	0.06
senior_mf_coef	coefficient for senior-only household in a multi-family building	1.00	0.2
no_pay_coef	coefficient for household does not pay for hot water	1.00	0.2

7-B.5   SAMPLE CALCULATION USING THE HOT WATER DRAW MODEL

Table 7-B.5.1 and Figure 7-B.5.1 provide a sample calculation and results for a 40-gallon water heater and common values for the hot water draw model variables.

Table 7-B.5.1   Sample Hot Water Draw Model Calculation for a 40-Gallon Water Heater

| Variable	Values				Coefficients				Gallons			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Sea_coef					1.73	-14.60	-4.72	10.46	1.7	-14.6	-4.7	10.5
per	3				0.974				2.9			
$age1$	0				6.393				0			
$age2$	1				10.518				10.5			
$age3$	2				15.305				30.6			
$age4$	0				15.305				0			
T_{tank}	120 ºF				-0.128				-15.4			
$Tanksz$	40 gal				0.144				5.8			
T_{in}	56.0	68.7	64.2	51.2	-0.179				-10.0	-12.3	-11.5	-9.2
T_{air}	55.3	74.1	57.9	37.5	0.512				28.3	37.9	29.7	19.2
$athome$	1				10.219				10.2			
dw_adj	1				-.207 *(0.692 * per + 1.335 *√per)				-0.9			
cw_adj	1				-.464*(1.1688*per +4.7737 *√per)				-5.4			
$senior\_mf$	0				1				1			
no_pay	0				1				1			
Total Gallons per Day									**58.3**	**49.4**	**51.8**	**58.8**
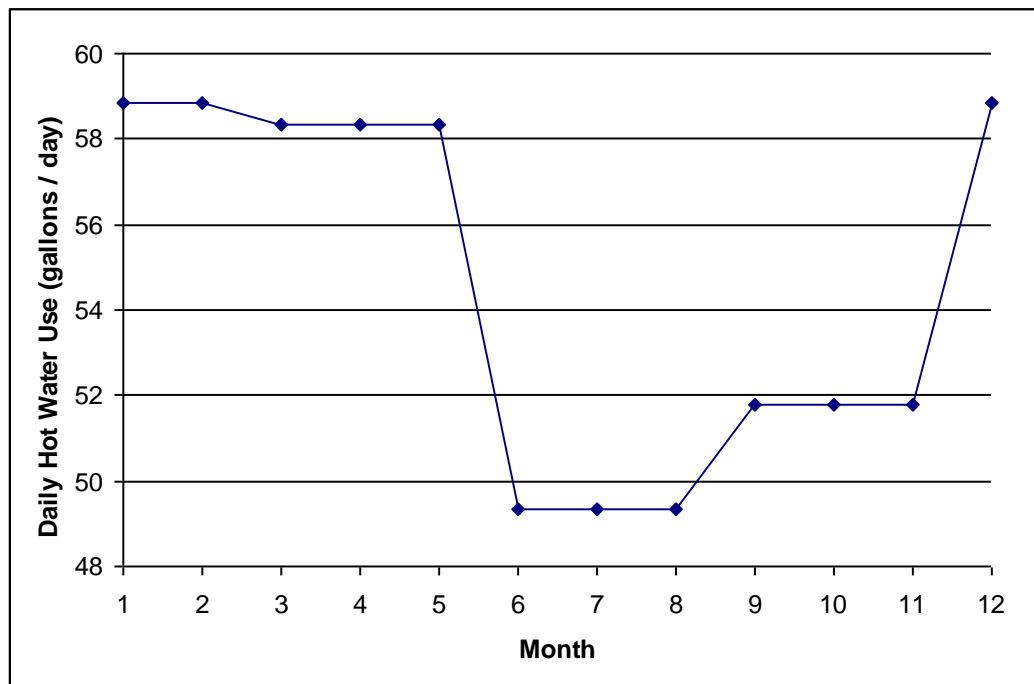
Figure 7-B.5.1   Average Daily Hot Water Use for Sample Calculation

7-B.6   REGIONAL AVERAGE DAILY HOT WATER USE VOLUMES

Figures 7-B.6.1 to 7-B.6.4 show the range of average daily hot water use volumes for each product class and region. For oil-fired storage water heaters, data was only available for the listed regions.
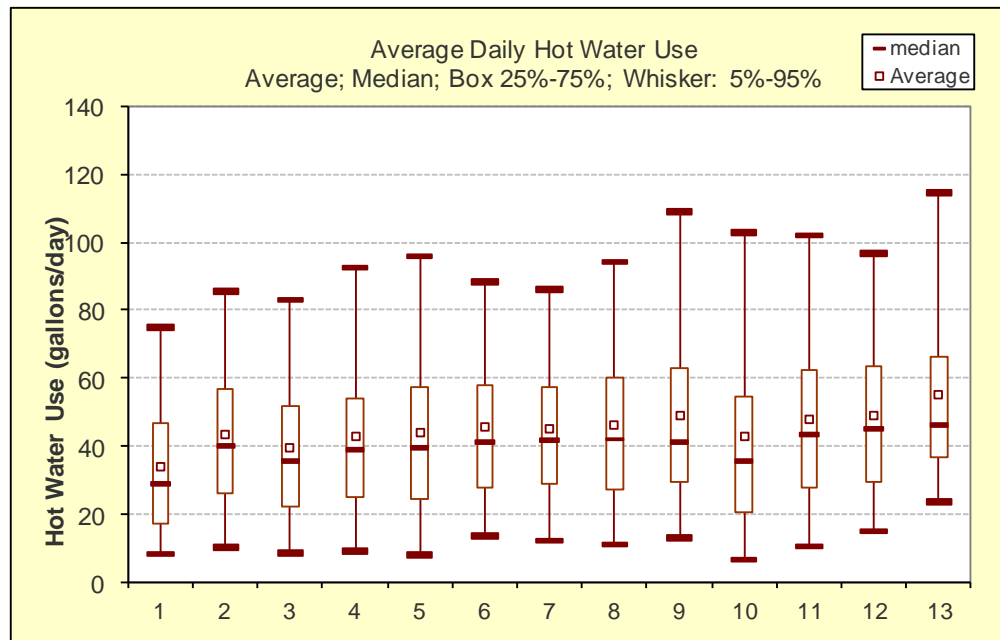

Figure 7-B.6.1   Regional Average Daily Hot Water Use for Gas-Fired Storage Water Heaters
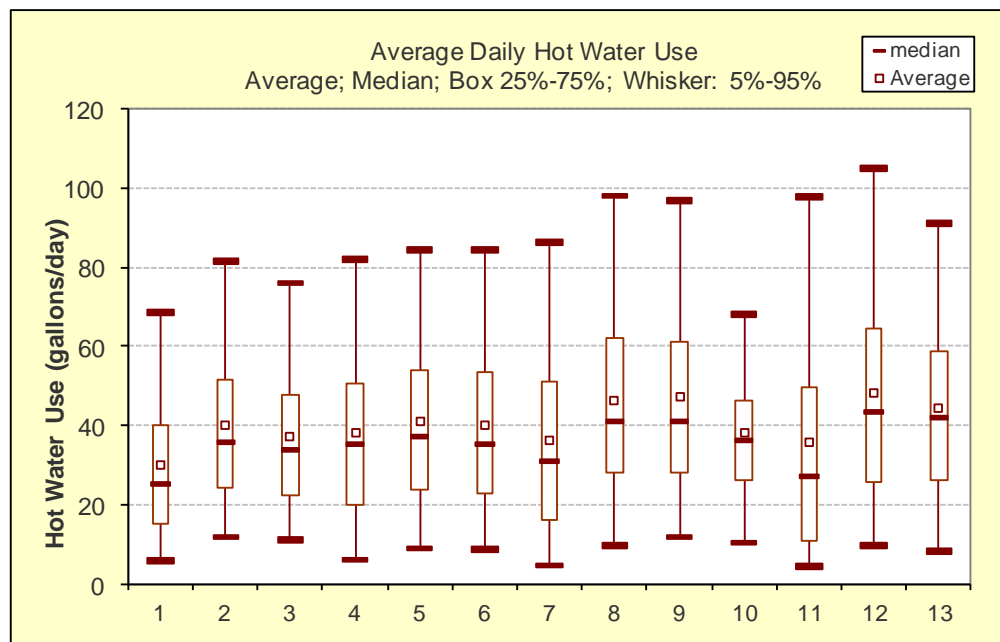

Figure 7-B.6.2   Regional Average Daily Hot Water Use for Electric Storage Water Heaters
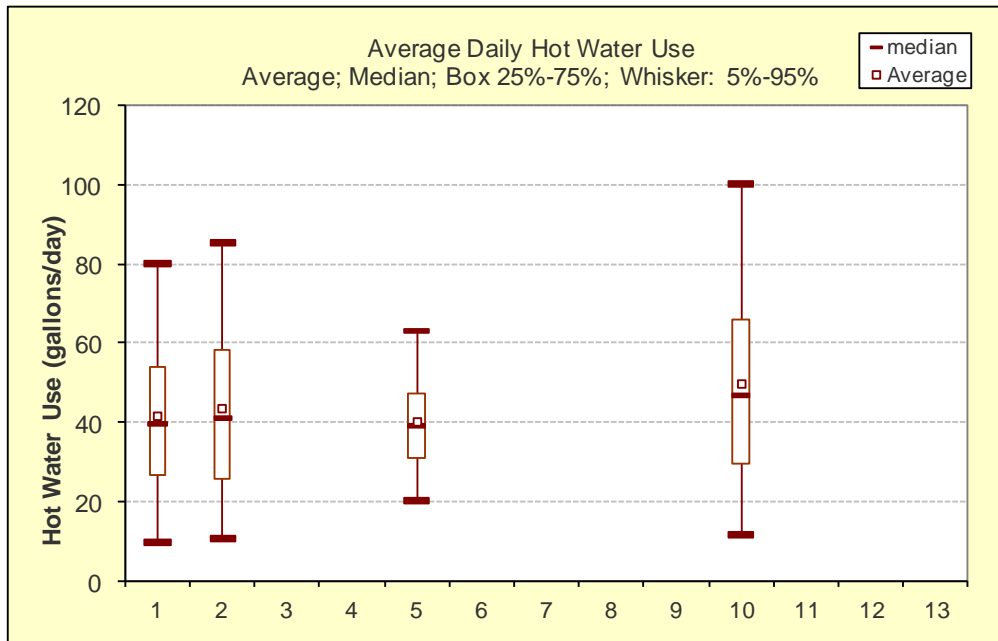
Figure 7-B.6.3   Regional Average Daily Hot Water Use for Oil-Fired Storage Water Heaters
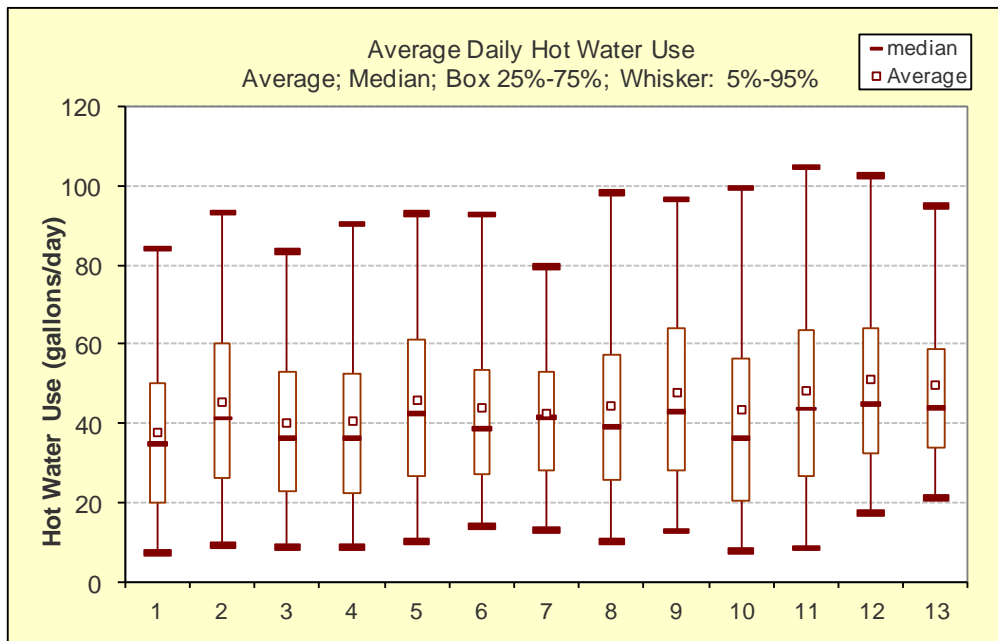

Figure 7-B.6.4   Regional Average Daily Hot Water Use for Gas-Fired Instantaneous Water Heaters

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4.   U.S. Department of Energy - Energy Efficiency & Renewable Energy, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment, Residential Dishwashers, Dehumidifiers, and Cooking Products, and Commercial Clothes Washers*, 2007. Washington, DC.