

APPENDIX 7-E. DERIVATION OF HEATING LOAD FOR DIRECT HEATING EQUIPMENT AND POOL HEATERS

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7-E.1 INTRODUCTION

RECS 2005 provides variables for the energy consumption for direct heating equipment and pool heaters. DOE used this information to determine the annual house heating load (HHL) and pool heater heating load (PHHL).

7-E.2 DIRECT HEATING EQUIPMENT

7-E.2.1 Derivation of House Heating Load for Direct Heating Equipment

Annual house heating load (HHL) is determined using the DOE's test procedure¹ approach as follows. First, from the test procedure the average annual fuel energy for gas or oil vented heaters, E_F , for single-stage direct heating equipment is given by the following equation:

$$E_F = BOH_{SS} \times (Q_{IN} - Q_P) + 8760 \times Q_P$$

Then the burner operating hours (BOH_{SS}) can be rewritten as follows using DOE's test procedure equation for BOH_{SS} and substituting in the HHL:

$$BOH_{SS} = HHL \times A - 4160 \times A \times Q_P \times \eta_U$$

Finally, the HHL is determined by replacing E_F with the RECS 2005² calculated annual energy consumption ($Q_{YR,RECS}$) and adding an adjustment factor to account for future improvements to the building shell and increases in home area:

$$HHL = \left(\frac{Q_{YR,RECS} - 8760 \times Q_P}{A \times (Q_{IN} - Q_P)} + 4160 \times Q_P \times \eta_U \right) * Adj_Factor$$

Where:

$Q_{YR,RECS}$ =	annual heating fuel use from RECS 2005, kBtu/yr,
Q_P =	pilot input rate, Btu/h,
Q_{IN} =	rated input capacity of direct heating equipment, Btu/h,
8760 =	hours in a year, h,
4160 =	average heating season hours according to test procedure, h,
A =	test procedure factor, h/kBtu,
	100,000
	$\frac{341,000 \times PE + (Q_{in} - Q_P) \times \eta_U}{}$,
PE =	DHE power consumption while the burner is on, W,
η_U =	part load utilization efficiency (%),

$$\eta_{ss} = \frac{2950 AFUE \times \eta_{ss} \times Q_{in}}{2950 \times \eta_{ss} \times Q_{in} - AFUE \times 2.033 \times 4600 \times Q_p},$$

η_{ss} = steady state efficiency (%), and
 Adj_Factor = adjustment factor.

The average pilot input rate for the above calculation is 400 Btu/h for gas wall fan DHE and gas wall gravity DHE, 450 Btu/h for gas floor DHE, and 350 Btu/h for gas room DHE.³ Chapter 7 describes the input capacity (Q_{IN}) values.

The PE value reflects a design with electrical components. DOE used values for PE given in the 1993 technical support document.³

The adjustment factor (Adj_Factor) takes into account future improvements to the building shell and increases in home area based on Early Release version (December 2009) of EIA's 2010 Annual Energy Overview (*AEO 2010*) projections for retrofit and new construction in 2013.⁴

The steady state efficiency (η_{ss}) is calculated by solving for η_{ss} in the equation given in section 4.1.17 in the DOE test procedure as follows:

$$\eta_{ss} = \frac{AFUE + 1.78 \times D_F + 189 \times D_S - 129 \times P_F - 2.8 \times L_J + 1.81}{0.968}$$

The DOE test procedure gives values for the parameters D_F , D_S , P_F , and L_J .

7-E.2.2 Adjustment to Direct Heating Equipment Energy Consumption using RECS

For the households for which it is clear that the natural gas use for heating is associated solely with use of the direct heating equipment as primary or secondary heating equipment, DOE used the annual heating fuel consumption variable for the housing unit from RECS 2005.²

For the households that use direct heating equipment as secondary heating equipment and also use primary gas heating equipment other than direct heating equipment, DOE made adjustments to the household heating load by using a RECS variable which reports the fraction of heating energy consumption provided by the primary heating system. Using this variable, DOE estimated the fraction of heating provided by the secondary direct heating equipment (see Table 7-E.2.1) using a triangular distribution.

Table 7-E.2.1 Adjustment of RECS Energy Consumption for Secondary DHE

RECS Value for EQMAMT	RECS Value Definition (How much heat main heating equipment provides)	Fraction of DHE Heating (%)		
		Min	Avg	Max
1	Almost all	5	15	25
2	About three-fourths	15	25	35
3	Close to half of all your heat	35	40	45
6	Don't know	5	25	45

7-E.3 POOL HEATERS

7-E.3.1 Derivation of Pool Heaters Heating Load for Pool Heaters

Annual pool heaters heating load (PHHL) is determined using the DOE test procedure as follows.⁵ First, from the test procedure the average annual fuel energy for gas pool heaters, E_F , is given by the following equation:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_P$$

Then the burner operating hours (BOH_{SS}) can be written as follows:

$$BOH_{SS} = \frac{PHHL}{Q_{IN} \times E_t}$$

DOE determined the PHHL by replacing E_F with the RECS 2001-2005^{2, 6} calculated annual energy consumption (Q_{RECS}):

$$PHHL = \left(\frac{Q_{IN}}{Q_{IN} - Q_P} \right) (Q_{RECS} - Q_P \times POH) \times E_t$$

Finally, because Q_P is much smaller than Q_{IN} for pool heaters, DOE approximated the PHHL using the following formula:

$$PHHL = (Q_{RECS} - Q_P \times POH) \times E_t$$

Where:

Q_{RECS} = Pool heater annual fuel consumption (kBtu/yr),
 Q_P = pilot light input rate (kBtu/yr),
 POH = pool operating hours (h/yr), and
 E_t = thermal efficiency of the household's existing pool (%).

For units with a pilot light, DOE assigned a pilot light input rate of 1,000 Btu/h.^{3, 7} DOE assigned pool heaters with pilot lights to 26.5 percent of households based on the fraction of

models in the May 2008 FTC pool heater directory.⁸ DOE estimated the remaining 73.5 percent were equipped with electronic ignition.

The DOE test procedure uses an average value for pool operating hours (POH) of 4,464 hours per year. DOE used a distribution around this average to assign POH to the sample households. The distribution ranges from 235 h/yr to 8760 h/year (100 percent of the time). The value of 235 h/year is the minimum value that fits the function used to calculate the distribution, and is close to the minimum number of hours that a pool heater burner can operate.

DOE assigned the sample households an existing pool heater having thermal efficiency of 78-percent. Thus, for example almost all pool heaters associated with RECS 2005 households were installed after 1989 (based on a maximum lifetime for pool heaters of 16 years), which was after EPCA mandated the 78-percent energy conservation standard.

7-E.3.2 Adjustment of Energy Consumption from RECS

Pool heater annual fuel consumption (Q_{RECS}) for each household with a pool heater comes from RECS 2001-2005. In most cases the fuel energy consumption in RECS 2001-2005 includes other gas appliances such as gas clothes dryers and/or gas cooking equipment. For households having a pool heater and gas clothes dryers and/or gas cooking equipment, DOE subtracted the energy use of this equipment from the fuel energy consumption provided in RECS. DOE estimated that the energy gas clothes dryers and/or gas cooking equipment by developing a normal distribution based on households without pool heaters that had different combinations of clothes dryers and/or gas cooking equipment, with a minimum value equal to zero and a maximum value of twice the average (see Table 7-E.3.1).

Table 7-E.3.1 Distribution Parameters for the Adjustment of RECS Energy Consumption for Pool Heaters

Gas equipment in households with pool heaters	Average Annual Energy Consumption Subtracted ($kBtu/h$)		Standard Deviation	
	RECS2005	RECS2001	RECS2005	RECS2001
Cooking Equipment Only	6,805	4,315	6,669	4,075
Clothes Dryer Only	7,354	7,235	5,320	2,084
Cooking Equipment and Clothes Dryer	13,521	10,892	7,470	4,675

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