

**APPENDIX E-2. UNCERTAINTY OF ENERGY PARAMETERS
EF, RE, UA, AND P_{on}**

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APPENDIX E-2. UNCERTAINTY OF ENERGY PARAMETERS EF, RE, UA, AND Pon

E-2.1 ENERGY FACTOR (EF)

Estimated uncertainty ranges for the energy factors (EFs) of different design options were provided for the typical tank size of electric (50-gal) and gas (40-gal) water heaters by an LBNL consultant.¹ Ratios were developed to represent the minimum and maximum variations in the EF values of the typical tank sizes. Since each design option is a combination of several single designs, the ratio of a combined design option is assigned to be the largest among the single designs involved. For example, gas-fired water heater Design Option 3 (78% RE and 2" Insulation) is a combination of four single designs, the Analytic Baseline, Heat Traps, 78% RE, and 2" Jacket Insulation. The uncertainty range of Design Option 3 is the largest range of these four single designs. This ensures that the estimated uncertainty ranges include those of every single design.

Then, by multiplying the ratios of the different design options by their corresponding EF values, the maximum and minimum EF values of all the standard tank sizes were calculated. The resulting uncertainty ranges for EF are characterized by the minimum, the most-likely, and the maximum, so that the probability distribution can be described by a simple triangular distribution. The uncertainty ranges are also in compliance with the Code of Federal Regulation ruling that specifies that reported EF values must be no higher than the mean value of the sample of the tested units.² In both electric and gas water heaters, the largest range of the EF is within 5% of the value in our simulation study. For oil water heaters, range of EF is set to 2%.

The determination of the ranges of uncertainty for recovery efficiency (RE), standby heat loss coefficient (UA), and rated input (Pon) is made using the Water Heater Analysis Model (WHAM). They are estimated by assessing how big the ranges of these parameters can be to yield the reported ranges of uncertainty on EF independently. To achieve this, the partial derivative of EF to each of the three parameters—RE, UA, and Pon, is computed. The width of the range is reduced slightly to account for the effect on EF when two parameters vary simultaneously. It was found that EF is far less sensitive to Pon than the other two parameters.

E-2.2 RECOVERY EFFICIENCY (RE)

The set of equations to solve RE for a given EF is:

$$RE_{\max} = RE_{\text{likely}} \times \left| 1 - \frac{1}{\sqrt{2}} \right| + \frac{EF_{\max} \times 41094 \times (UA \times 67.5 - Pon)}{Pon \times (1620 \times EF_{\max} \times UA - 41094) \times \sqrt{2}}$$

$$RE_{\min} = RE_{\text{likely}} \times \left| 1 - \frac{1}{\sqrt{2}} \right| + \frac{EF_{\min} \times 41094 \times (UA \times 67.5 - Pon)}{Pon \times (1620 \times EF_{\min} \times UA - 41094) \times \sqrt{2}}$$

E-2.3 STANDBY HEAT LOSS COEFFICIENT (UA)

Similarly, the range of uncertainty for UA can be determined by the following set of equations:

$$UA_{\max} = UA_{\text{likely}} \times \left| 1 - \frac{1}{\sqrt{2}} \right| + \frac{Pon \times \left(\frac{RE}{EF_{\min}} - 1 \right)}{67.5 \times \left(RE \times Pon \times \frac{24}{41094} - 1 \right) \times \sqrt{2}}$$

$$UA_{\min} = UA_{\text{likely}} \times \left| 1 - \frac{1}{\sqrt{2}} \right| + \frac{Pon \times \left(\frac{RE}{EF_{\max}} - 1 \right)}{67.5 \times \left(RE \times Pon \times \frac{24}{41094} - 1 \right) \times \sqrt{2}}$$

E-2.4 RATED INPUT (Pon)

Since the variation in Pon has an negligible effect on the uncertainty of EF, the determination of the uncertainty is independent of the EF value. Therefore, the minimum and the maximum numbers from the LBNL water heater database were used, as listed below:

Table E-2.1 Uncertainty of Rated Input

	Pon_{min}	Pon_{likely}	Pon_{max}
Electric Water Heater (30-gal)	4606	15354	18766
Electric Water Heater (other sizes)	12966	15354	18766
Gas Water Heater (30-gal)	26000	30000	40000
Gas Water Heater (40-gal)	28000	40000	60000
Gas Water Heater (50-gal)	32000	50000	75000
Gas Water Heater (75-gal)	55000	75000	75000
Oil Water Heater (32-gal)	84000	90000	105000
Oil Water Heater (50-gal)	105000	105000	105000

REFERENCES

1. Minniear, M., *Residential Water Heaters: Initial Estimates of Manufacturing Costs and Energy Consumption*, November 12, 1997, Minniear Corporation. Panama City, FL. Report No. Task 1 of LBNL Subcontract No. 6466797.
2. *Title 10, Code of Federal Regulations, Part 430- Energy Conservation Program for Consumer Products, Section 430.24(e)(1)(ii)*, January 1, 1998.