APPENDIX 6A. COOKTOPS AND OVENS: DETERMINATION OF ENERGY-USING COMPONENTS

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APPENDIX 6A. COOKTOPS AND OVENS: DETERMINATION OF ENERGY-USING COMPONENTS

6A.1 INTRODUCTION

As presented in Chapter 6, section 6.4.1.2, based on recent survey data, DOE determined that the representative annual energy consumption of an electric range is 281.5 kWh per year. Because DOE's analysis of cooking products consisted of analyzing oven and cooktop product classes, DOE had to disaggregate the range energy consumption into the portion allocated to the oven and the portion allocated to the cooktop. In addition, because oven and cooktop energy use may consist of several energy-using components (i.e., cooking, ignition, self-cleaning, and clock) and potential increases in efficiency may affect only a subset of these components, DOE had to further disaggregate the oven and cooktop energy consumption into its specific energy-using components. The following sections detail: (1) DOE's method for disaggregating the representative electric range energy consumption into the various energy-using components of electric ovens and cooktops; and (2) DOE's method for establishing the representative energy use of gas cooking product energy-using components based on the values that were determined for the electric cooking product energy-using components.

6A.2 METHODOLOGY FOR DISAGGREGATING ELECTRIC RANGE ANNUAL ENERGY CONSUMPTION

As noted above, DOE determined that the representative annual energy consumption of an electric range is 281.5 kWh per year. Based on the following equation, DOE assumed the energy consumption was equal to the sales weighted-average of standard and self-cleaning oven energy consumption plus the cooktop energy consumption. Also included is the clock power associated with electric ovens.

$$\begin{aligned} \boldsymbol{UEC_{elec\,cooking}} &= 281.5\,\boldsymbol{kWh/yr} \\ &= \boldsymbol{MSe_{SC}} \times \left(\boldsymbol{E_{CO_SC}} + \boldsymbol{Ees} \times \boldsymbol{S_e}\right) + \left(1 - \boldsymbol{MSe_{SC}}\right) \times \boldsymbol{E_{CO_STD}} + \boldsymbol{E_{CA}} + \left(\boldsymbol{P_{CL}} \times 8760 \times 0.001\right) \end{aligned}$$

where:

$UEC_{elec\,cooking}$ =	Annual energy consumption of electric cooking (kWh/yr),
MSe_{SC} =	Market share of electric ovens that are self-cleaning, 63.2%,[1]
E_{CO_SC} =	Annual cooking energy consumption of self-cleaning electric ovens (kWh/yr),
Ees =	Typical self-cleaning energy consumption per cycle for electric self-cleaning ovens, 5.286 kWh (as reported in Chapter 6, Table 6.4.7),
S_e =	Number of self-clean cycles per year for electric self-cleaning ovens according to the DOE test procedure, 4,[2]

E_{CO_STD} =	Annual cooking energy consumption of standard electric ovens (kWh/yr),
E_{CA} =	Annual energy consumption of electric cooktops (kWh/yr),
P_{CL} =	Power input to clock (watts), 2,[a]
8760 =	Hours in a year, and
0.001 =	Conversion to convert watts in kW.

DOE estimated the annual cooking energy consumption of electric self-cleaning ovens as a fraction of the cooking energy consumption of a standard electric oven. The annual cooking energy consumption of cooktops was also estimated as a fraction of the cooking energy consumption of standard ovens. These fractions were taken from the ratios of energy consumption as established by the DOE test procedure. The following equations represent the calculations used by DOE:

$$\boldsymbol{E_{CO_SC}} = \boldsymbol{Re_{SC_STD}} \times \boldsymbol{E_{CO_STD}}$$

$$\boldsymbol{E_{CA}} = \boldsymbol{Re_{CT_STD}} \times \boldsymbol{E_{CO_STD}}$$

where:

Re_{SC_STD} =	Ratio of annual self-cleaning electric oven cooking energy to annul standard electric cooking energy, and
Re_{CT_STD} =	Ratio of annul electric cooktop cooking energy to annual standard electric oven cooking energy.

To calculate each of the above ratios, DOE took the annual useful cooking energy output values from the DOE test procedure and divided them by the baseline cooking efficiencies reported in Chapter 6, Table 6.4.1. For cooktops, this assumes that the ratio of the cooktop and oven annual useful cooking energy output value has not changed significantly over time, even though there has been a decrease in the annual energy consumption of electric cooking products.

$$\boldsymbol{Re_{SC_STD}} = \frac{\left(\boldsymbol{O_O} / \boldsymbol{EFFeo_{SC}}\right)}{\left(\boldsymbol{O_O} / \boldsymbol{EFFeo_{STD}}\right)} = 0.881$$

$$\boldsymbol{Re_{CT_STD}} = \frac{\left(\boldsymbol{O_{CT}} / \boldsymbol{EFFe_{CT}}\right)}{\left(\boldsymbol{O_O} / \boldsymbol{EFFeo_{STD}}\right)} = 0.971$$

where:

[a] DOE assumed a clock power consumption of 2 watts for purposes of disaggregating the electric range annual energy consumption into its energy-using components. As reported in Chapter 6, the baseline clock power consumption for electric standard and self-cleaning ovens are 3.9 watts and 3.8 watts, respectively.

O_O =	Annual useful cooking energy output for ovens according to the DOE test procedure, 29.3 kWh,[2]
O_{CT} =	Annual useful cooking energy output for cooktops according to the DOE test procedure, 173.1 kWh, [2]
$EFFeo_{SC}$ =	Cooking efficiency of the baseline self-cleaning electric oven, 13.79%,
$EFFeo_{STD}$ =	Cooking efficiency of the baseline standard electric oven, 12.15%, and
$EFFe_{CT}$ =	Cooking efficiency of the baseline electric cooktop, 74.0%.

The baseline cooking efficiency of electric cooktops (74%) is the sales weighted-average efficiency of coil and smooth cooktops.

$$\boldsymbol{EFFe_{CT}} = \boldsymbol{MSe_{COIL}} \times \boldsymbol{EFFe_{CT_COIL}} + \left(1 - \boldsymbol{MSe_{COIL}}\right) \times \boldsymbol{EFFe_{CT_SMTH}}$$

where:

MSe_{SC} =	Market share of electric cooktops that are coil, 46.3%,[1]
$EFFe_{CT_COIL}$ =	Cooking efficiency of the baseline electric coil cooktop, from the cost/efficiency table, 73.7%, and
$EFFe_{CT_SMTH}$ =	Cooking efficiency of the baseline electric smooth cooktop, from the cost/efficiency table, 74.2%.

With both the annual cooking energy consumption of self-cleaning electric ovens and electric cooktops expressed as a function of standard electric oven annual cooking energy consumption, DOE solved for the standard electric oven annual cooking energy consumption by the using the following equation:

$$\boldsymbol{E_{CO_STD}} = \frac{281.5 - \boldsymbol{MSe_{SC}} \times \boldsymbol{Ees} \times \boldsymbol{S_e} - \boldsymbol{P_{CL}} \times 8760 \times 0.001}{\boldsymbol{MSe_{SC}} \times \boldsymbol{Re_{SC_STD}} + 1 - \boldsymbol{MSe_{SC}} + \boldsymbol{Re_{CT_STD}}}$$

$$= \frac{281.5 - 63.2\% \times 5.286 \times 4 - 2 \times 8760 \times 0.001}{63.2\% \times 0.881 + 1 - 63.2\% + 0.971} = 132.4\,\boldsymbol{kWh/yr}$$

With the standard electric oven annual cooking energy consumption established (E_{AO_STD}), DOE solved for the self-cleaning electric oven and cooktop annual cooking energy consumption values by using the following equations:

$$\boldsymbol{E_{CO_SC}} = \boldsymbol{Re_{SC_STD}} \times \boldsymbol{E_{CO_STD}}$$
$$= 0.881 \times 132.4 = 116.6\,\boldsymbol{kWh/yr}$$

$$\boldsymbol{E_{CA}} = \boldsymbol{Re_{CT_STD}} \times \boldsymbol{E_{CO_STD}}$$
$$= 0.971 \times 132.4 = 128.3\,\boldsymbol{kWh/yr}$$

Table 6A.2.1 summarizes the energy-using components of electric cooking products. Also provided are the annual useful cooking energy output values—one set based on the DOE test procedure and another set deduced from the lower annual energy consumption values.

Table 6A.2.1 Electric Cooking Products: Energy-Using Components

Energy-Using Components	Cooktop	Standard Oven	Self-Cleaning Oven
Cooking Efficiency	74.0%	12.15%	13.79%
Cooking Energy (kWh/yr)	128.2	132.4	116.6
Self-Cleaning Energy (kWh/yr)			21.1
Clock (kWh/yr)*		34.2	33.3
Total (kWh/yr)	128.2	166.5	171.0
Annual Useful Cooking Energy Output (O_{CT} for cooktops; O_O for ovens)			
Current DOE test procedure (kWh)	173.1	29.3	29.3
Based on electric range annual cooking energy of 281.5 kWh/yr (kWh)	94.8	16.1	16.1

* Clock energy based on clock power of 3.9 W for standard ovens and 3.8 W for self-cleaning ovens.

6A.3 METHODOLOGY FOR ESTABLISHING GAS COOKING ENERGY-USING COMPONENTS

DOE estimated the annual energy consumption of gas cooking products based on the lower (revised) annual useful cooking energy output values that DOE deduced from the electric range annual energy consumption of 281.5 kWh per year. As represented by the following equations, DOE assumed that the ratio of the revised-to-current annual useful energy output values for electric cooking products applied to gas cooking products as well:

$$O_{O_GAS_REV} = O_{O_GAS_DOE} \times \frac{O_{O_ELEC_REV}}{O_{O_ELEC_DOE}} = 88.8\,kBtu \times \frac{16.1\,kWh}{29.3\,kWh} = 48.7\,kBtu$$

$$O_{CT_GAS_REV} = O_{CT_GAS_DOE} \times \frac{O_{CT_ELEC_REV}}{O_{CT_ELEC_DOE}} = 527.6\,kBtu \times \frac{94.8\,kWh}{173.1\,kWh} = 288.9\,kBtu$$

where:

$O_{O_GAS_REV}$ = Revised annual useful cooking energy output for gas ovens,
$O_{O_GAS_DOE}$ = DOE test procedure annual useful cooking energy output for gas ovens,
$O_{O_ELEC_REV}$ = Revised annual useful cooking energy output for electric ovens,
$O_{O_ELEC_DOE}$ = DOE test procedure annual useful cooking energy output for electric ovens,
$O_{CT_GAS_REV}$ = Revised annual useful cooking energy output for gas cooktops,

$O_{CT_GAS_DOE}$ = DOE test procedure annual useful cooking energy output for gas cooktops,
$O_{CT_ELEC_REV}$ = Revised annual useful cooking energy output for electric cooktop, and
$O_{CT_ELEC_DOE}$ = DOE test procedure annual useful cooking energy output for electric cooktops.

With the revised annual useful cooking output values known for gas cooking products, DOE used the following test procedure equations to calculate the annual cooking energy consumption of gas cooking products. In the equations below, DOE used the baseline cooking efficiencies reported in Chapter 6, Table 6.4.1.

$$E_{CO_SC_GAS} = \frac{O_{O_GAS_REV}}{EFFgo_{SC}} = \frac{48.7\,kBtu}{7.13\%} = 683.5\,kBtu/yr$$

$$E_{CO_STD_GAS} = \frac{O_{O_GAS_REV}}{EFFgo_{STD}} = \frac{48.7\,kBtu}{5.92\%} = 822.6\,kBtu/yr$$

$$E_{CC_GAS} = \frac{O_{CT_GAS_REV}}{EFFg_{CT}} = \frac{288.9\,kBtu}{39.9\%} = 724.4\,kBtu/yr$$

where:

$E_{CO_SC_GAS}$ = Annual cooking energy consumption of gas self-cleaning ovens,
$EFFgo_{SC}$ = Cooking efficiency of the baseline self-cleaning gas oven, 7.13%,
$E_{CO_STD_GAS}$ = Annual cooking energy consumption of gas standard ovens,
$EFFgo_{STD}$ = Cooking efficiency of the baseline standard gas oven, 5.92%,
E_{CC_GAS} = Annual cooking energy consumption of gas cooktops, and
$EFFg_{CT}$ = Cooking efficiency of the baseline gas cooktop, 39.9%.

Table 6A.3.1 summarizes the energy-using components of gas cooking products. Also provided are the annual useful cooking energy output values—one set based on the DOE test procedure and the other based on the revised set of values. Ignition, self-cleaning, and clock energy consumption values are described and reported in Chapter 6, Tables 6.4.5, 6.4.8, and 6.4.9 for gas cooktops, standard ovens, and self-cleaning ovens, respectively.

Table 6A.3.1 Gas Cooking Products: Energy-Using Components

Energy-Using Components	Cooktop		Standard Oven		Self-Cleaning Oven
	With pilot	Without pilot	With pilot	Without pilot	
Cooking Efficiency	39.9%	39.9%	5.92%	5.92%	7.13%
Cooking Energy (MMBtu/yr)	0.72	0.72	0.82	0.82	0.68
Self-Cleaning Energy					
Gas (MMBtu/yr)					0.17
Electric (kWh/yr)					0.7
Ignition					
Gas (MMBtu/yr)	2.02		1.01		
Electric (kWh/yr)				21.1	21.1
Clock (kWh/yr)*					31.5
Total					
Gas (MMBtu/yr)	2.74	0.72	1.83	0.82	0.85
Electric (kWh/yr)				21.1	55.1
Annual Useful Cooking Energy Output (O_{CT} for cooktops; O_O for ovens)					
Current DOE test procedure (kBtu)	527.6		88.8		88.8
Revised values (kBtu)	288.9		48.7		48.7

* Clock energy based on clock power of 3.6 W for self-cleaning ovens.

REFERENCES

[1] Association of Home Appliance Manufacturers. *AHAM Data on Cooking Products for Efficiency Standards Rulemaking,* August 23, 2006. Letter to Building Technologies Program, U.S. Department of Energy.

[2] U.S. Office of the Federal Register. *Code of Federal Regulations, Title 10, Energy. Part 430, Subpart B, Appendix I: Uniform Test Method for Measuring the Energy Consumption of Conventional Ranges, Conventional Cooking Tops, Conventional Ovens, and Microwave Ovens,* 2006. Washington, DC.