TECHNICAL SUPPORT DOCUMENT FOR RESIDENTIAL COOKING PRODUCTS
(Docket Number EE-RM-S-97-700)

VOLUME 2: POTENTIAL IMPACT OF ALTERNATIVE EFFICIENCY LEVELS FOR RESIDENTIAL COOKING PRODUCTS

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Prepared for

U.S. DEPARTMENT OF ENERGY
Office of Codes and Standards

TABLE OF CONTENTS
VOLUME 2 - RESIDENTIAL COOKING PRODUCTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The product type analyzed in this Technical Support Document (TSD) includes consumer products that are used as the major household cooking appliances (cooktops, ovens, and microwave ovens). In 1987, the National Appliance Energy Conservation Act (NAECA) was established which set minimum energy efficiency standards for thirteen household appliances, including "kitchen ranges and ovens". With regard to cooking products NAECA specified only that gas kitchen ranges and ovens having an electrical supply cord shall not be equipped with a constant burning pilot as of January 1, 1990. This TSD analyzes higher efficiency levels for this product type.

Kitchen ranges and ovens are categorized into fifteen product classes. Eight of these product classes have been analyzed and seven have not been analyzed. Since the Notice of Proposed Rulemaking (NOPR) was published in March, 1994 two new product classes have been added and subsequently exempted. These two product classes are commercial cooktops and ovens which were added based on written comments and oral testimony from the NOPR (See Section 1.2). Additional microwave oven product classes were requested by written comments to the NOPR, but they were not established due to insufficient data (See Section 1.2).

Design options are changes that can be incorporated into the design of a gas or electric cooktop, oven, or microwave oven to improve its efficiency (or reduce its energy consumption). The design options for the various product classes can be found in Sections 1.3.1, 1.4.1, and 1.5.1. Several design options have been eliminated based on NOPR written comments and subsequent analysis. These include: "Reduced Burner Excess Air" (gas cooktops), "Remove Oven Door Window" (all ovens), "Reflective Surfaces" (all ovens), "Added Insulation" (all ovens), "Reduced Thermal Mass" (all ovens), and "Modified Wave Guide" (microwave ovens).

Based on comments received during the NOPR review, an analysis is presented on gas ranges, i.e., combined cooktop and oven. According to recent shipment data, gas ranges account for approximately 87% of the gas cooking products shipped. This analysis is an attempt to uncover any advantages or disadvantages associated with analyzing cooking products as they are more commonly sold. The analysis shows there could be cost savings in the range analysis due to shared manufacturing and installation costs between the cooktop and oven for the pilot-less ignition. The life-cycle costs and payback period are significantly reduced in this combined analysis approach. See Sections 1.6 and 4.1.3 for more details.

The annual useful cooking energy output is the cooking energy delivered to the food over the course of a year. It is used in the DOE test procedure calculations to calculate annual energy consumption for cooktops and ovens. However, estimates of annual cooking energy consumption have declined since the DOE test procedure was implemented in 1978 and later amended in 1979. An analysis was performed and published with the NOPR which used revised annual useful cooking energy output values to determine the annual energy consumption, meaning, the annual useful cooking energy output values were adjusted downward from the values used in the existing DOE test procedure. In March 1995, these revised annual useful cooking energy output values were proposed by DOE to replace the existing test procedure values. Based on testimony given during the public hearings on the NOPR and also written comments on the NOPR, DOE's proposed estimates for the annual useful cooking energy output values (and in turn, the annual energy consumption) were criticized as not being current and, as a result, being too high for all cooking products. Further analysis, performed on more recent reports and studies, demonstrated that a further reduction in residential cooking annual energy consumption appears to have occurred. New values for the annual useful cooking energy output were determined from the more recent annual energy consumption data. Residential cooking annual energy consumption based on the use of the most recent annual useful cooking energy output values have been incorporated into all the analyses in this TSD including 1) the engineering analysis, 2) the life-cycle cost and payback period analysis, 3) the consumer forecasting analysis, 4) the manufacturer impact analysis, 5) the utility analysis, and 6) the environmental analysis. For comparison purposes, annual energy consumption based on the use of the proposed annual useful cooking energy output values (those proposed by DOE in March, 1995) have also been incorporated into the engineering and payback period analyses. Table ES.1 below is a summary of the three sets of annual useful cooking energy output values which are of interest. See Sections A.1 and A.2 in Appendix A for more details.

Table ES.1 Summary of Annual Useful Cooking Energy Outputs

	DOE Existing Test Procedure[1]	**DOE Proposed Test Procedure**[2,3]	**Recent, field usage data**[4,5]
GAS (kBtu/yr)			
Cooktops	947.5	732.5	527.6
Oven, standard	160.7	124.2	88.8
Oven, self-Clean	160.7	124.2	88.8
ELECTRIC (kWh/yr)			
Cooktop, smooth	277.7	209.4	173.1
Cooktop, coil	277.7	209.4	173.1
Oven, standard	47.1	35.5	29.3
Oven, self-clean	47.1	35.5	29.3
Microwave Oven	34.2	77.3	79.8

1 Existing DOE Test Procedure, 10 CFR, Part 430, Subpart B, Appendix I, April, 1979.
2 Proposed DOE Test Procedure, FR 60(56), pp 15330-15363, March, 1995.
3 For microwave ovens, the current annual energy consumption of 143.2 kWh/yr was used by the proposed DOE test procedure to determine the annual useful cooking energy output value of 77.3 kWh/yr.
4 Most recent annual useful cooking energy output values; see Tables A.5 and A.6 in Volume 2, Appendix A of this TSD.
5 Based on written comments, the number of self-clean cycles per year for self-cleaning ovens has been reduced to 4 to compute annual useful cooking energy output values for these two product classes.

The energy efficiency descriptor for cooking products is the energy factor which is related to the amount of energy consumed by a given product. Table ES.2 below summarizes the energy consumption for each of the eight product classes as a function of five energy efficiency levels. Each energy efficiency level consists of a combination of design options that improve the overall efficiency of the product. A complete list of design options analyzed for each class and their resultant impact on energy consumption is provided in Chapter 1.

For each of the eight product classes analyzed in this TSD, Table ES.3 summarizes the life-cycle cost (LCC) results for each of the five energy efficiency levels and the baseline. LCCs were determined for an average electricity price of $0.0772/kWh and an average gas price of $5.94/MMBtu in 1995$. Equipment lifetimes are specified in Section 2.2 for each product class. Equipment prices and annual energy expenses for each class can be found in Chapter 4. It should be noted that annual energy expenses are determined from field-based energy use data (see Table ES.1 above) rather than energy use data determined with DOE test procedure calculations.

Table ES.2 Energy Consumption for Cooking Products[1]

	Energy Efficiency Level					
Product Class	Baseline	1	2	3	4	5
Cooktops						
Electric Coil (kWh/yr)	234.7	234.7	225.2	225.2	222.9	222.9
Electric Smooth (kWh/yr)	233.4	233.4	233.4	233.4	233.4	206.4
Gas (kBtu/yr)	3373	3373	3373	1323	1323	1256
Ovens						
Electric Standard (kWh/yr)	274.9	263.2	251.8	248.0	169.6	162.4
Electric Self-Cleaning (kWh/yr)	303.7	303.7	303.7	303.7	220.0	213.7
Gas Standard (kBtu/yr) [2]	2982	2982	2982	1524	1438	1359
Gas Self-Cleaning (kBtu/yr) [3]	1659	1659	1659	1659	1659	1358
Microwave Ovens (kWh/yr)	143.2	143.2	143.2	143.2	143.2	132.4

[1] Energy consumption values based on most recent annual useful cooking energy output values
[2] Values include electrical secondary cooking energy consumption; electrical energy consumption converted to kBtu with a factor of 3.412 kBtu/kWh
[3] Values include electrical secondary, clock, and self-cleaning cooking energy consumption; electrical energy consumption converted to kBtu with a factor of 3.412 kBtu/kWh

Table ES.3 Life-Cycle Costs for Cooking Products (@ 6% discount rate)

	Energy Efficiency Level					
Product Class	Baseline	1	2	3	4	5
Cooktops						
Electric Coil	$381	$381	$378	$378	$383	$383
Electric Smooth	$481	$481	$481	$481	$481	$1235
Gas	$442	$442	$442	$436	$436	$483
Ovens						
Electric Standard	$636	$629	$627	$641	$724	$853
Electric Self-Cleaning	$892	$892	$892	$892	$1007	$1173
Gas Standard	$677	$677	$677	$648	$655	$787
Gas Self-Cleaning	$981	$981	$981	$981	$981	$1167
Microwave Ovens	$312	$312	$312	$312	$312	$369

Table ES.4 shows the payback periods for the five energy efficiency levels. As with the LCCs, the payback periods are determined with an average electricity price of $0.0772/kWh and an average gas price of $5.94/MMBtu in 1995$. Also, annual energy expenses are determined with field-based energy use data. See Chapter 4 for more details on the payback period analysis.

Table ES.4 Payback Periods for Cooking Products (years)[1]

	Energy Efficiency Level				
Product Class	1	2	3	4	5
Cooktops					
Electric Coil	N/A	6.5	6.5	12.8	12.8
Electric Smooth	N/A	N/A	N/A	N/A	373.2
Gas	N/A	N/A	4.0	4.0	40.6
Ovens					
Electric Standard	3.8	6.2	13.8	22.0	36.2
Electric Self-Cleaning	N/A	N/A	N/A	29.0	51.7
Gas Standard	N/A	N/A	6.8	11.3	63.4
Gas Self-Cleaning	N/A	N/A	N/A	N/A	126.6
Microwave Ovens	N/A	N/A	N/A	N/A	78.8

1 Payback periods based on most recent annual useful cooking energy output values

Tables ES.5 and ES.6 show the results of a national consumer analysis that estimates cumulative national savings and national net present benefit to consumers. Table ES.5 details the impact of the five energy efficiency levels on the cooking product classes. Table ES.6 shows the net present value over the period 1999-2030. At an energy efficiency level of 3, the total net present value to society is $0.23 billion in 1990$.

Tables ES.7 through ES.10 show the results of the manufacturer impact analysis. These tables provide long- and short-run manufacturer impact data by detailing how shipments, price, revenue, net income, and return on equity are affected by the increased efficiency levels. Note that in the short-run, the energy efficiency levels have more of a negative impact on manufacturer's return on equity than in the long-run. Table ES.10 provides additional manufacturer impact data for the purpose of determining the industry's net present value for each of the five energy efficiency levels. More details on the manufacturer impact analysis can be found in Chapter 5.

Table ES.5 Energy Consumption and Savings for Cooking Products (Quadrillion Btu, Primary)

	Energy Efficiency Level					
	Baseline	1	2	3	4	5
Cumulative Electricity Use, 1999-2030						
Electric Cooktops	5.66	5.66	5.60	5.61	5.56	5.21
Gas Cooktops	2.41	2.41	2.41	2.22	2.23	2.32
Electric + Gas Cooktops	8.07	8.07	8.01	7.83	7.79	7.53
Electric Ovens	7.26	7.18	7.10	7.15	5.58	5.59
Gas Ovens	2.81	2.81	2.82	2.50	2.67	2.44
Electric + Gas Ovens	10.08	10.00	9.92	9.66	8.25	8.03
Microwave Ovens	5.40	5.40	5.40	5.40	5.40	5.07
Total Energy Use, 1999-2030	23.55	23.47	23.33	22.89	21.44	20.63
Cumulative Energy Savings, 1999-2030						
Electric Cooktops		0.00	0.05	0.05	0.10	0.45
Gas Cooktops		0.00	0.00	0.19	0.18	0.09
Electric + Gas Cooktops		0.00	0.05	0.24	0.28	0.54
Electric Ovens		0.08	0.17	0.11	1.68	1.68
Gas Ovens		0.00	-0.01	0.31	0.15	0.37
Electric + Gas Ovens		0.08	0.16	0.42	1.83	2.05
Microwave Ovens		0.00	0.00	0.00	0.00	0.33
Total Energy Savings, 1999-2030		0.08	0.21	0.66	2.11	2.92

Table ES.6 Net Present Value, Benefits, and Costs to Society of Efficiency Levels for Cooking Products Purchased from 1999-2030 (Billion 1990 Dollars, Discounted at 7% Real)

	Energy Efficiency Level				
	1	2	3	4	5
Cooktops					
Energy Savings	0.00	0.10	0.23	0.28	0.49
Equipment Cost	0.00	0.06	0.13	0.29	4.43
Net Present Value	0.00	0.03	0.11	-0.01	-3.95
Ovens					
Energy Savings	0.11	0.22	0.60	2.34	2.70
Equipment Cost	0.04	0.13	0.48	4.76	12.03
Net Present Value	0.07	0.09	0.12	-2.41	-9.33
Microwave Ovens					
Energy Savings	N/A	N/A	N/A	N/A	0.47
Equipment Cost	N/A	N/A	N/A	N/A	5.14
Net Present Value	N/A	N/A	N/A	N/A	-4.67

Table ES.7a Long-Run Manufacturer Impacts for Cooktops

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	1.43	1.43	1.44	1.44	1.43	1.36
Percent Change		0.00%	0.11%	0.19%	-0.07%	-4.98%
Standard Error		0.63%	1.02%	1.55%	1.67%	13.42%
Price	$103.60	$103.60	$104.74	$105.18	$106.82	$144.68
Percent Change		0.00%	1.10%	1.52%	3.11%	39.65%
Standard Error		1.62%	1.94%	1.98%	2.69%	14.00%
Revenue (in million dollars)	148.65	148.65	150.45	151.20	153.16	197.27
Percent Change		0.00%	1.21%	1.72%	3.03%	32.70%
Standard Error		1.18%	1.63%	1.94%	2.32%	19.33%
Net Income (in million dollars)	7.85	7.85	7.85	7.89	7.95	9.15
Difference		0.00	0.01	0.04	0.11	1.30
Standard Error		0.11	0.19	0.25	0.33	3.80
Return on Equity	10.84%	10.84%	10.77%	10.78%	10.78%	10.42%
Difference		0.00%	-0.07%	-0.06%	-0.05%	-0.42%
Standard Error		0.10%	0.18%	0.21%	0.28%	2.25%

Table ES.7b Short-Run Manufacturer Impacts for Cooktops

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	1.43	1.43	1.44	1.44	1.43	1.36
Percent Change		-0.03%	0.07%	0.15%	-0.10%	-4.82%
Price	$103.60	$103.74	$104.90	$105.35	$106.95	$143.78
Percent Change		0.14%	1.26%	1.69%	3.24%	38.79%
Revenue (in million dollars)	148.65	148.81	150.63	151.40	153.32	196.37
Percent Change		0.11%	1.33%	1.85%	3.14%	32.10%
Net Income (in million dollars)	7.85	8.02	8.06	8.11	8.12	8.11
Difference		0.17	0.21	0.00	0.28	0.27
Return on Equity	10.84%	11.07%	11.04%	11.08%	11.02%	9.24%
Difference		0.24%	0.21%	0.24%	0.18%	-1.59%
Standard Error		1.30%	1.39%	1.67%	1.18%	3.46%

Table ES.8a Long-Run Manufacturer Impacts for Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	1.049	1.049	1.049	1.046	0.982	0.847
Percent Change		0.05%	-0.01%	-0.24%	-6.36%	-19.29%
Standard Error		0.39%	0.78%	1.53%	8.02%	12.06%
Price	$213.17	$213.58	$214.47	$217.41	$259.12	$342.42
Percent Change		0.19%	0.61%	1.99%	21.56%	60.63%
Standard Error		0.59%	0.68%	1.08%	7.40%	20.58%
Revenue (in million dollars)	223.61	224.15	224.95	227.52	254.53	289.91
Percent Change		0.24%	0.60%	1.75%	13.82%	29.65%
Standard Error		0.42%	0.75%	1.41%	9.83%	23.22%
Net Income (in million dollars)	11.65	11.65	11.67	11.66	12.38	13.04
Difference		0.00	0.02	0.01	0.73	1.39
Standard Error		0.08	0.15	0.34	2.53	7.91
Return on Equity	10.53%	10.51%	10.51%	10.35%	10.33%	9.75%
Difference		-0.02%	-0.02%	-0.17%	-0.19%	-0.77%
Standard Error		0.05%	0.08%	0.23%	1.76%	4.87%

Table ES.8b Short-Run Manufacturer Impacts for Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	1.049	1.049	1.048	1.046	0.986	0.858
Percent Change		0.01%	-0.05%	-0.26%	-5.97%	-18.16%
Price	$213.17	$213.77	$214.64	$217.51	$259.91	$332.90
Percent Change		0.28%	0.69%	2.04%	20.52%	56.17%
Revenue (in million dollars)	223.61	224.26	225.05	227.57	253.41	285.79
Percent Change		0.29%	0.64%	1.77%	13.32%	27.81%
Net Income (in million dollars)	11.65	11.79	11.80	11.50	10.60	6.88
Difference		0.14	0.16	-0.15	-1.05	-4.77
Return on Equity	10.53%	10.64%	10.63%	10.21%	8.85%	5.14%
Difference		0.11%	0.10%	-0.32%	-1.68%	-5.38%
Standard Error		0.42%	0.74%	0.72%	2.79%	7.04%

Table ES.9a Long-Run Manufacturer Impacts for Microwave Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	0.720	0.720	0.720	0.720	0.720	0.620
Percent Change		0.00%	0.00%	0.00%	0.00%	-13.54%
Standard Error		0.00%	0.00%	0.00%	0.00%	9.71%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$203.60
Percent Change		0.00%	0.00%	0.00%	0.00%	34.66%
Standard Error		0.00%	0.00%	0.00%	0.00%	11.70%
Revenue (in million dollars)	109.23	109.23	109.23	109.23	109.23	127.16
Percent Change		0.00%	0.00%	0.00%	0.00%	16.42%
Standard Error		0.00%	0.00%	0.00%	0.00%	14.33%
Net Income (in million dollars)	2.01	2.01	2.01	2.01	2.01	2.59
Difference		0.00	0.00	0.00	0.00	0.58
Standard Error		0.00	0.00	0.00	0.00	1.75
Return on Equity	3.65%	3.65%	3.65%	3.65%	3.65%	4.18%
Difference		0.00%	0.00%	0.00%	0.00%	1.16%
Standard Error		0.00%	0.00%	0.00%	0.00%	3.03%

Table ES.9b Short-Run Manufacturer Impacts for Microwave Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in millions)	0.722	0.722	0.722	0.722	0.722	0.631
Percent Change		0.00%	0.00%	0.00%	0.00%	-12.68%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$199.55
Percent Change		0.00%	0.00%	0.00%	0.00%	31.98%
Revenue (in million dollars)	109.23	109.23	109.23	109.23	109.23	125.87
Percent Change		-0.00%	-0.00%	-0.00%	-0.00%	15.24%
Net Income (in million dollars)	2.01	2.01	2.01	2.01	2.01	1.24
Difference		0.00	0.00	0.00	0.00	-0.77
Return on Equity	3.65%	3.65%	3.65%	3.65%	3.65%	2.30%
Difference		-0.00%	-0.00%	-0.00%	-0.00%	-1.35%
Standard Error		0.00%	0.00%	0.00%	0.00%	5.34%

Table ES.10a Manufacturer Impacts for the Purpose of Determining Net Present Value for Cooktops

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in million)	7.17	7.09	7.10	7.10	7.08	6.68
Difference		-0.08	-0.08	-0.07	-0.09	-0.50
Percent Change		-1.16%	-1.07%	-0.99%	-1.29%	-6.94%
Price	$103.60	$109.30	$110.48	$110.93	$112.82	$156.53
Difference		5.70	6.88	7.33	9.22	52.93
Percent Change		5.50%	6.64%	7.08%	8.90%	51.09%
Total Revenue (in million dollars)	743.27	775.04	784.16	787.96	798.97	1045.05
Difference		31.77	40.89	44.69	55.70	301.78
Percent Change		4.27%	5.50%	6.01%	7.49%	40.60%
Profit after Tax (in million dollars)	28.54	31.63	31.86	32.12	33.49	64.23
Difference		3.09	3.31	3.57	4.95	35.69
Percent Change		10.83%	11.61%	12.52%	17.35%	125.05%
Net Cash Flow (in million dollars)	22.97	20.66	19.33	18.94	18.45	7.36
Difference		-2.31	-3.64	-4.02	-4.52	-15.61
Percent Change		-10.06%	-15.84%	-17.52%	-19.66%	-67.97%
Industry Value (in million dollars)	191.39	197.95	198.12	198.61	200.16	228.34
Difference		6.55	6.73	7.21	8.77	36.95
Percent Change		3.42%	3.52%	3.77%	4.58%	19.31%

Table ES.10b Manufacturer Impacts for the Purpose of Determining Net Present Value for Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in million)	5.25	5.20	5.20	5.18	4.81	4.08
Difference		-0.04	-0.04	-0.07	-0.44	-1.16
Percent Change		-0.77%	-0.85%	-1.26%	-8.32%	-22.18%
Price	$213.17	$217.50	$218.47	$222.33	$270.62	$368.64
Difference		4.33	5.30	9.16	57.45	155.47
Percent Change		2.03%	2.49%	4.30%	26.95%	72.93%
Total Revenues (in million dollars)	1118.06	1131.96	1136.16	1151.44	1301.24	1504.58
Difference		13.89	18.10	33.37	183.17	386.51
Percent Change		1.24%	1.62%	2.98%	16.38%	34.57%
Profit after Tax (in million dollars)	42.93	44.50	44.77	49.45	70.67	108.61
Difference		1.57	1.84	6.51	27.74	65.68
Percent Change		3.65%	4.28%	15.17%	64.61%	152.98%
Net Cash Flow (in million dollars)	34.55	33.76	33.31	35.39	31.15	34.52
Difference		-0.79	-1.24	0.84	-3.40	-0.03
Percent Change		-2.30%	-3.59%	2.44%	-9.84%	-0.08%
Industry Value (in million dollars)	287.90	291.47	291.96	292.47	318.89	348.06
Difference		3.56	4.06	4.56	30.99	60.16
Percent Change		1.24%	1.41%	1.59%	10.77%	20.90%

Table ES.10c Manufacturer Impacts for the Purpose of Determining Net Present Value for Microwave Ovens

		Energy Efficiency Level				
	1996 Base	1	2	3	4	5
Shipments (in million)	3.61	3.61	3.61	3.61	3.61	3.07
Difference		0.00	0.00	0.00	0.00	-0.54
Percent Change		0.00%	0.00%	0.00%	0.00%	-14.95%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$210.47
Difference		0.00	0.00	0.00	0.00	59.27
Percent Change		0.00%	0.00%	0.00%	0.00%	39.20%
Total Revenues (in million dollars)	546.13	546.13	546.13	546.13	546.13	646.54
Difference		0.00	0.00	0.00	0.00	100.41
Percent Change		0.00%	0.00%	0.00%	0.00%	18.38%
Profit after Tax (in million dollars)	20.97	20.97	20.97	20.97	20.97	27.60
Difference		0.00	0.00	0.00	0.00	6.62
Percent Change		0.00%	0.00%	0.00%	0.00%	31.59%
Net Cash Flow (in million dollars)	16.88	16.88	16.88	16.88	16.88	6.43
Difference		0.00	0.00	0.00	0.00	-10.45
Percent Change		0.00%	0.00%	0.00%	0.00%	-61.89%
Industry Value (in million dollars)	140.63	140.63	140.63	140.63	140.63	155.04
Difference		0.00	0.00	0.00	0.00	14.41
Percent Change		0.00%	0.00%	0.00%	0.00%	10.25%

Table ES.11 shows the present value of net revenue losses for electric utilities at a 5% real utility discount rate for all energy efficiency levels and for two cases regarding regulatory behavior; one case (1998-2002) which assumes that regulators will adjust rates to reflect the reduced energy sales in five years that result from more efficient cooking products, and another case (1998-2030), which assumes that they never adjust rates. The present value of net revenue losses may range from $0 to 71 million for a five-year lag, and, if regulators did not adjust rates, utilities could actually loose revenues of as much as $1.24 billion. The present value over the period 1998 to 2030 also represents the rate increase needed over this period to compensate for decreased revenues, assuming that regulators adjust them immediately. Refer the Chapter 6 for more details regarding utility impact analysis.

Table ES.11 Cumulative Present Value of Revenue Losses for Cooking Products (MM $1990)

	Energy Efficiency Level				
Regulatory Lag	1	2	3	4	5
Cooktops					
1998 to 2002	0	4	3	4	13
1998 to 2030	0	39	27	53	231
Ovens					
1998 to 2002	2	5	2	44	44
1998 to 2030	41	84	41	839	827
Microwave Ovens					
1998 to 2002	0	0	0	0	14
1998 to 2030	0	0	0	0	185

Tables ES.12a through 12c summarize the results of the environmental impact analysis for energy efficiency level 3. The reduction in power plant emissions of sulfur dioxide (SO_2), nitrogen oxides (No_x), and carbon dioxide (CO_2) are shown. Refer to Chapter 7 for more detail at all five energy efficiency levels.

Table ES.12a Projected Emissions for Cooktops at Energy Efficiency Level 3 for SO_2, NO_x, and CO_2

SO_2

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.11	0.13	-0.01	-0.01	0.10	0.11	0.00
2005	0.41	0.46	-0.04	-0.04	0.37	0.41	0.01
2010	0.50	0.56	-0.05	-0.06	0.45	0.50	0.02
2015	0.37	0.41	-0.09	-0.10	0.28	0.31	0.01
2020	0.15	0.16	-0.08	-0.09	0.07	0.07	0.00
2025	-0.04	-0.05	-0.07	-0.07	-0.11	-0.12	-0.01
2030	-0.08	-0.09	-0.08	-0.09	-0.16	-0.18	-0.01
Cumulative SO_2 reduction (kt):	5				(short tons):	6 000	

NO_x

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.09	0.09	0.02	0.02	0.10	0.11	0.00
2005	0.33	0.37	0.06	0.07	0.40	0.44	0.01
2010	0.44	0.48	0.13	0.14	0.56	0.62	0.02
2015	0.34	0.38	0.19	0.21	0.53	0.58	0.02
2020	0.15	0.16	0.21	0.24	0.36	0.40	0.02
2025	-0.05	-0.05	0.23	0.26	0.19	0.21	0.01
2030	-0.10	-0.11	0.25	0.27	0.15	0.17	0.01
Cumulative NO_x reduction (kt):	11				(short tons):	12 000	

CO_2

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.03	0.04	0.02	0.02	0.05	0.05	0.00
2005	0.14	0.15	0.06	0.07	0.20	0.22	0.02
2010	0.19	0.21	0.13	0.14	0.32	0.35	0.02
2015	0.18	0.19	0.19	0.20	0.36	0.40	0.03
2020	0.09	0.10	0.22	0.24	0.30	0.34	0.02
2025	-0.03	-0.03	0.24	0.26	0.21	0.23	0.01
2030	-0.08	-0.09	0.25	0.28	0.17	0.19	0.01
Cumulative CO_2 reduction (Mt):	8				(short tons):	8 000 000	

Table ES.12b Projected Emissions for Ovens at Energy Efficiency Level 3 for SO_2, NO_x, and CO_2

SO_2

Year	Abated from Power Plants kt	Abated from Power Plants thousand short tons	Abated from In-House kt	Abated from In-House thousand short tons	Total Reduction in Emissions kt	Total Reduction in Emissions thousand short tons	Reduction as a % of Total Res. Emissions
2000	0.09	0.09	-0.03	-0.03	0.06	0.06	0.00
2005	0.27	0.29	-0.07	-0.07	0.20	0.22	0.01
2010	0.46	0.51	-0.09	-0.10	0.37	0.41	0.01
2015	0.56	0.61	-0.15	-0.16	0.41	0.45	0.02
2020	0.50	0.55	-0.16	-0.18	0.34	0.37	0.02
2025	0.40	0.45	-0.16	-0.18	0.24	0.27	0.01
2030	0.31	0.35	-0.15	-0.16	0.17	0.18	0.01
Cumulative SO_2 reduction (kt):	9				(short tons):	10 000	

NO_x

Year	Abated from Power Plants kt	Abated from Power Plants thousand short tons	Abated from In-House kt	Abated from In-House thousand short tons	Total Reduction in Emissions kt	Total Reduction in Emissions thousand short tons	Reduction as a % of Total Res. Emissions
2000	0.06	0.07	0.02	0.02	0.08	0.09	0.00
2005	0.22	0.24	0.11	0.12	0.32	0.36	0.01
2010	0.40	0.44	0.20	0.23	0.61	0.67	0.02
2015	0.52	0.57	0.29	0.31	0.80	0.88	0.03
2020	0.50	0.55	0.31	0.34	0.81	0.89	0.04
2025	0.44	0.49	0.33	0.36	0.77	0.85	0.04
2030	0.39	0.42	0.34	0.38	0.73	0.80	0.04
Cumulative NO_x reduction (kt):	19				(short tons):	21 000	

CO_2

Year	Abated from Power Plants Mt	Abated from Power Plants million short tons	Abated from In-House Mt	Abated from In-House million short tons	Total Reduction in Emissions Mt	Total Reduction in Emissions million short tons	Reduction as a % of Total Res. Emissions
2000	0.02	0.03	0.02	0.02	0.04	0.05	0.00
2005	0.09	0.10	0.11	0.12	0.19	0.21	0.01
2010	0.18	0.20	0.20	0.23	0.38	0.42	0.03
2015	0.26	0.29	0.28	0.31	0.55	0.61	0.04
2020	0.30	0.33	0.31	0.34	0.61	0.67	0.04
2025	0.31	0.34	0.32	0.36	0.63	0.70	0.04
2030	0.31	0.35	0.35	0.38	0.66	0.73	0.04
Cumulative CO_2 reduction (Mt):	14				(short tons):	15 000 000	

Table ES.12c Projected Emissions for Microwave Ovens at Energy Efficiency Level 3 for SO_2, NO_x, and CO_2

SO_2

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumulative SO_2 reduction (kt):		0			(short tons):	0 000	

NO_x

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumulative NO_x reduction (kt):		0			(short tons):	0 000	

CO_2

Year	Abated from Power Plants		Abated from In-House		Total Reduction in Emissions		Reduction as a % of Total Res. Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumulative CO_2 reduction (Mt):		0			(short tons):	0 000	

CHAPTER 1. ENGINEERING ANALYSIS

1.1 INTRODUCTION

This product type includes consumer products that are used as the major household cooking appliance. They are designed to cook or to heat different types of food using gas or electricity. Electricity may be used for resistance or microwave heating. This product type includes horizontal cooking surfaces (cooktops) and either conventional or microwave ovens or combinations of these product classes.

The Department of Energy (DOE) test procedure is based on measuring the amount of energy required to raise a test load from room temperature to a specified temperature above room temperature. For conventional gas and electric cooktops the test load is made from aluminum, and for ovens the test load is made from black anodized aluminum. The size of the load depends on the application. For microwave ovens, the test load is a prescribed amount of water in a suitable container. The DOE has recently proposed (1) that the International Electrotechnical Commission (IEC) test procedure for microwave ovens be adopted (2). The IEC test procedure is already used by both foreign and U.S. manufacturers.

Cooktops, conventional ovens, and microwave ovens are rated using an energy factor. The energy factor is expressed as a percent and is the ratio of the annual useful cooking energy output of the cooking appliance (energy conveyed to the item being heated) to its total annual energy consumption. The annual energy consumption includes the energy input during the time the load is being heated plus the energy consumed by other features such as a clock, standing pilot, electronic ignition system, or self-cleaning cycles. The existing DOE test procedure provides values for the annual useful cooking energy output. When the test was developed in the mid-1970s, the annual useful cooking energy output values were representative of the way in which cooking appliances were used. Since the development of the test procedure, the use of cooking appliances has significantly changed. Revised annual useful cooking energy output values have been developed from metered data and conditional demand analyses performed by gas and electric utilities. These values have been adopted into the proposed DOE test procedure (3) and will be presented later in a discussion of energy use data for each of the different cooking appliances (i.e., cooktops, ovens, microwave ovens). In addition to the annual useful cooking energy output values used in the proposed DOE test procedure, another set of values have been derived based on more recent estimates of annual energy consumption. These more recent annual useful cooking energy output values will also be presented later in the discussion of energy use data. Range and oven energy usage values based on the more recent annual useful cooking energy output values have been used in all the impact analyses presented in this Technical Support Document (TSD) including 1) the consumer forecasting analysis, 2) the life-cycle cost and payback period analysis, 3) the manufacturer impact analysis, 4) the utility analysis, and 5) the environmental analysis. See Appendix A, Sections A.1 and A.2 for more details regarding the annual useful cooking energy output values.

The DOE test procedure also defines the efficiency of the cooking appliance, and it is important not to confuse it with the energy factor. The efficiency is analogous to a steady-state efficiency as its value is calculated from measurements taken only during the time the load is being heated. Unlike the energy factor, the efficiency does not include the energy consumption of such items as a clock or standing pilot.

For microwave ovens, the IEC test procedure specifies that one liter of water is heated through a temperature rise of 10°C at maximum microwave power. The microwave power output *P*, in watts, is calculated from the following formula:

$$P = 4187 \bullet \frac{\Delta T}{t} \tag{1.1}$$

where ΔT is the measured change in water temperature (in °C) and *t* is the time (in minutes) that the microwave generator is operating at full power. The energy factor is calculated by dividing *P* by the electric power input during the test.

Manufacturing

A typical large volume manufacturer of ranges and ovens relies on a mix of automated and manual processes in the production flow. Fabrication is becoming more automated as an increasing number of individual manual processes are being converted. The assembly process remains almost exclusively manual. A manufacturing flow diagram for conventional ovens is shown in Figure 1.1.

Automation is used for fabrication of the outer housing and inner liner. The porcelainizing facility applies two types of surfaces, one for conventional and self-cleaning ovens and one for continuous-cleaning units. Heating elements are purchased, as are all controls, wires, and insulation. For microwave ovens, the magnetrons (the heating elements) are all purchased from foreign manufacturers. For conventional ovens, fiberglass insulation, which is stuffed and wrapped in place, is used throughout, except where mineral fiber is used (in areas generating the most heat). After final assembly, units are inspected, tested, and packaged for shipping.

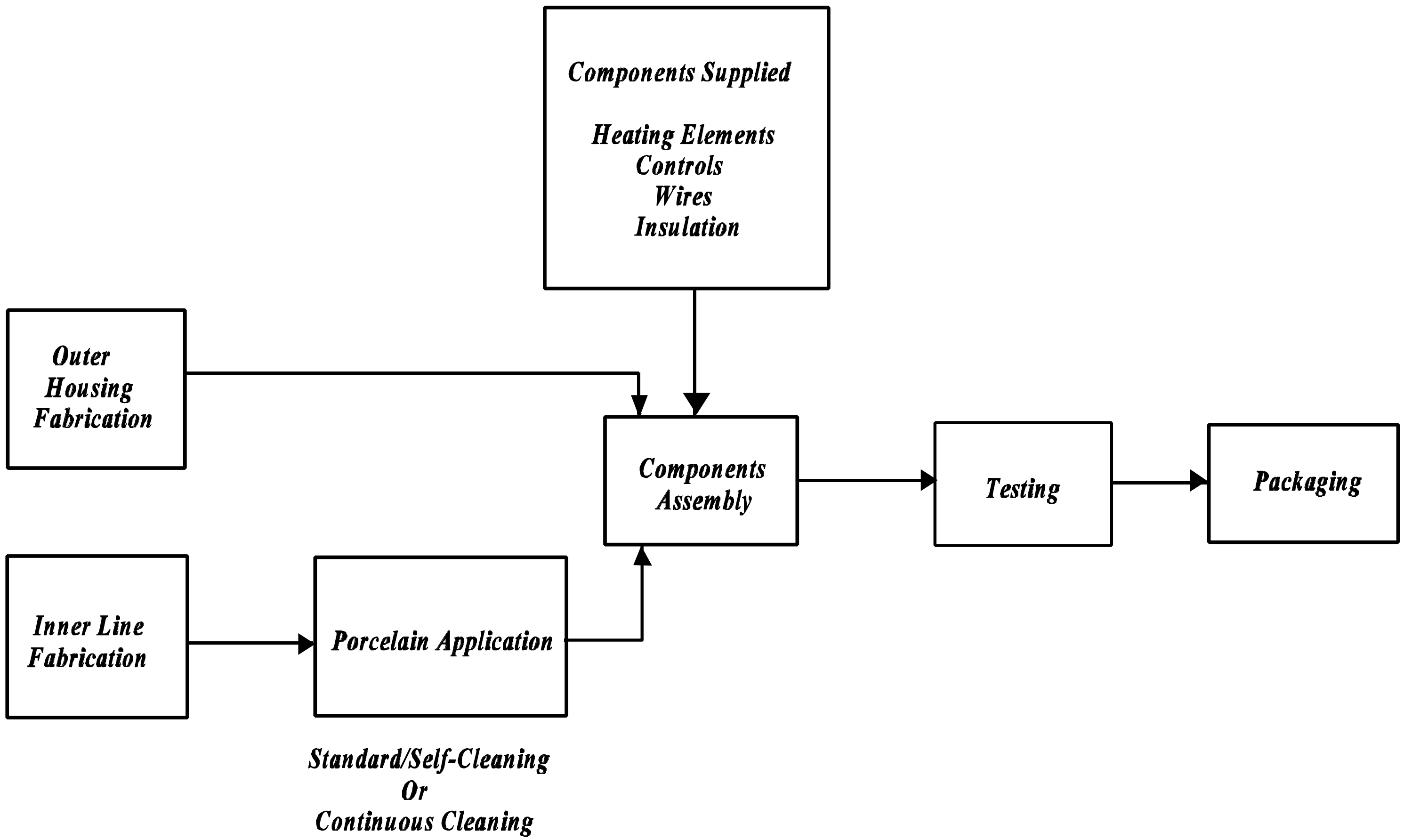

Figure 1.1 Manufacturing Flow Diagram for Kitchen Ranges and Ovens

1.2 PRODUCT CLASSES

The National Appliance Energy Conservation Act (NAECA) does not provide a basis for selecting product classes since minimum efficiency standards were never proposed within NAECA for ranges and ovens. NAECA specifies only that gas kitchen ranges and ovens having an electrical supply cord shall not be equipped with a constant burning pilot as of January 1, 1990. The Advanced Notice of Proposed Rulemaking (ANOPR) provided an extensive list of classes for all ranges and ovens. But during the review process for the Notice of Proposed Rulemaking (NOPR), the number of product classes proposed for analysis was significantly reduced. This is in part due to the decision to drop from consideration product classes for ranges (combination cooktop and oven appliance). Also, at the request of the industry, two new product classes have been established for gas products, commercial type cooktops and commercial type ovens. These will be described in more detail in later subsections.

The classes and energy efficiency levels developed for cooktops and ovens will apply to the individual components of the range (i.e,. cooktop and oven). This obviates the need to develop separate classes and energy efficiency levels for ranges. However, a short analysis of ranges is presented in Section 1.6 for informational purposes to show the effect of combined design options in a range. The product classes that have been established for cooktops and ovens are listed in Table 1.1.

Table 1.1 Product Classes for Cooktops and Ovens

Electric Cooktops
1. Low or High Wattage Open (Coil) Elements
2. Smooth Elements
3. Grill with or without Down Draft Feature
4. Griddle with or without Down Draft Feature
Gas Cooktops
5. Conventional Burners
6. Grill with or without Down Draft Feature
7. Griddle with or without Down Draft Feature
8. Warming/Simmer Burners
9. Commercial Type
Electric Ovens
10. Standard Oven with or without a Catalytic Line
11. Self-Clean Oven
Gas Ovens
12. Standard Oven with or without a Catalytic Line
13. Self-Clean Oven
14. Commercial Type
Microwave Ovens
15. Microwave Oven

For electric cooktops, a separate class was established for smooth elements because they are easier to clean than open (coil) elements. Cleanability is a consumer utility and warrants that a separate class be established for smooth elements. An electric cooktop consisting of four solid disk elements is the representative baseline unit for smooth elements. Induction cooking, halogen lamps, and radiant elements were considered as design options for smooth cooktops and assessed according to the economic characteristics of the particular designs. Although separate product classes were previously established in the ANOPR for grill and griddle cooktops, an engineering analysis was not performed on them. They account for about 3.5% of all electric cooktops sold in the U.S. The primary reason for not performing the engineering analysis is the lack of empirical data for these cooktops. After an extensive literature search, no data was found that detailed the cooking performance of electric grills and griddles. This is probably due in part to the DOE test procedure, as it does not apply to grills and griddles.

For gas cooktops, gas utilities and manufacturers have commented that separate classes should be maintained for cooktops with and without an electrical power cord (4). Since cooktops equipped without electrical cords have the capability of operating during electricity outages, gas utilities and manufacturers assert that these cooktop types provide a unique consumer utility. However, power outages are not frequent and long enough to consider lack of electric power a significant utility; between 90 and 93% of residential electricity customers experience no electricity outages longer than four hours per year (5). The consumer utility associated with the inability to cook during a power outage is considered different from a loss of heating capability during severe cold weather since the loss of home heating for a few hours is a much severer loss of utility to the consumer than the loss of ability to cook for that same period of time. Designs that require electricity will be evaluated on their economic advantages and disadvantages. Some classes listed in the ANOPR (e.g., sealed and radiant burners) are considered as design options. These designs do not provide a unique utility to the consumer. Gas grills and griddles, as well as warming/simmer burners, will not have an engineering analysis performed for them. They account for less than 3% of gas cooktops sold in the U.S. The lack of empirical data, probably due in part to the inability of the DOE test procedure to measure their energy consumption, is the primary reason for not performing analyses for these cooktop types.

For electric ovens, classes for standard and self-clean ovens were analyzed. The type of oven-cleaning system is a utility feature that affects performance. The three types of oven-cleaning systems are the standard, the continuous-cleaning, and the self-cleaning system. The standard, or non-cleaning, oven is cleaned by the consumer and uses no direct energy for cleaning. The continuous-cleaning system is a catalytic process whereby, during normal operation, soil is soaked onto the oven surface, which is coated with an oxidizing catalyst. The self-cleaning system is a pyrolytic process, whereby soil is oxidized during a special self-cleaning cycle. Self-cleaning ovens have added insulation because they operate at higher temperatures during the cleaning cycle than during cooking. The continuous-cleaning oven tends to be as energy-efficient as the standard oven. Even though the continuous-cleaning oven has greater utility than the standard oven, both continuous-cleaning and standard ovens are placed in the same product class because they tend to use the same amounts of energy. Since the self-cleaning oven uses energy during the cleaning cycle and is better insulated, its energy consumption is different from the standard and continuous-cleaning ovens. And since the self-cleaning oven provides a new utility to the consumer, it is in a separate product class. Oven types that were listed in the ANOPR as classes (i.e., forced convection for cooking, forced convection for cleaning, halogen lamp, and steam cooking) were analyzed for the NOPR as design options and have also been included here. These oven designs offer no unique consumer utilities. Thus, no additional classes are established for them.

For gas ovens, as with electric ovens, only classes for standard and self-clean ovens were established in the NOPR. As with gas cooktops, additional classes for ovens equipped with and without electrical cords were not adopted. Designs requiring electricity will be evaluated on their economic advantages and disadvantages. Oven classes listed in the ANOPR (i.e., radiant burner and convection) will be considered as design options as they offer no unique consumer utility that warrants their addition as classes.

Stand-alone microwave ovens with and without browning elements accounted for almost 97% of domestic shipments of microwaves in 1989 (6). The consensus of NOPR comments from industry requested 5 additional product classes which include: Portable Microwave Only (cavity volume < 0.8 ft^3), Portable Microwave Only (cavity volume of 0.8 to 1.19 ft^3), Portable Microwave Only (cavity volume $\geq$ 1.2 ft^3), Portable Microwave/Thermal (Convection), and Built-in (Fixed). However, there is insufficient data to analyze these types of microwave ovens. And, industry-supplied efficiency levels showed nearly a random scatter, thus separating these types by energy usage is also not possible. See Figure 1.2 and Table 1.3 on the following pages. Finally, the DOE test procedure for microwave ovens does not measure the energy use of the browning element or convection. For these reasons, there is no basis upon which to establish separate classes for these six types of microwave ovens.

Based on comments during the NOPR, a new product class for cooktops and ovens has been established: commercial-type gas cooktops and ovens. In general the commercial-type cooktop provides a different utility to the consumer since the typical commercial-type burner is of higher capacity (>14,000 Btu/hr, the standard gas burner is 9,000 Btu/hr). A new type of gas oven product class is also being established: the commercial-type gas oven. Below is a comparison table (Table 1.2) which shows the differences between the baseline and the commercial cooktop/oven.

Table 1.2. Comparison of Baseline and Commercial Cooktops/Ovens

	Cooktop		**Oven**	
	Baseline	**Commercial**	**Baseline**	**Commercial**
Burner Firing Rate (Btu/hr)	9000	>14,000	Ave of ~20,000	>22,500
Cavity Volume (ft^3)	---	---	3.9	$\geq$ 4.5*

* This volume requirement must allow for a 26-inch by 18-inch sheet pan, plus 1-inch on all sides, with typically a 14-inch height inside the oven.

In addition to the differences shown in Table 1.3, oven efficiency is known to depend on oven cavity volume, i.e., as the volume increases the efficiency decreases. If a new product class is not established for commercial cooktops/ovens, they would be forced to compete on an energy basis with standard cooking products with smaller oven cavities. Since the commercial cooking products were not factored into the baseline, they would be at a disadvantage in meeting energy efficiency targets based on this relationship. As a product class, their energy use is very minimal. AHAM (7) estimated the total shipments of commercial products as approximately 10,000 units in 1993. This estimate was based on telephone interviews with high-capacity manufacturers. The total gas and electric cooking unit production for 1993 was 6.6 million units. Therefore, the commercial products make up only 0.15 percent of the cooking market. There are clear differences between commercial and standard gas-fired range/ovens as demonstrated in Table 1.2 above. The oven volume of commercial products makes it nearly impossible to meet an energy efficiency level if they are put in the same product class with standard gas ovens. Based on the analysis above, commercial products as being considered as a separate product class ("high-capacity ranges/ovens"). However, due to the small number of shipments, insufficient engineering/cost data, higher burner firing-rate and larger cavity volume specifications, these products should be exempted.

The remainder of this section on ranges and ovens is split into the following four parts: cooktops, conventional ovens, microwave ovens, and gas ranges. Each part consists of a discussion on the following topics: design options, energy use data, and cost and efficiency data.

Figure 1.2 Microwave Oven Cavity Volume vs Efficiency
Based on AHAM data (6)

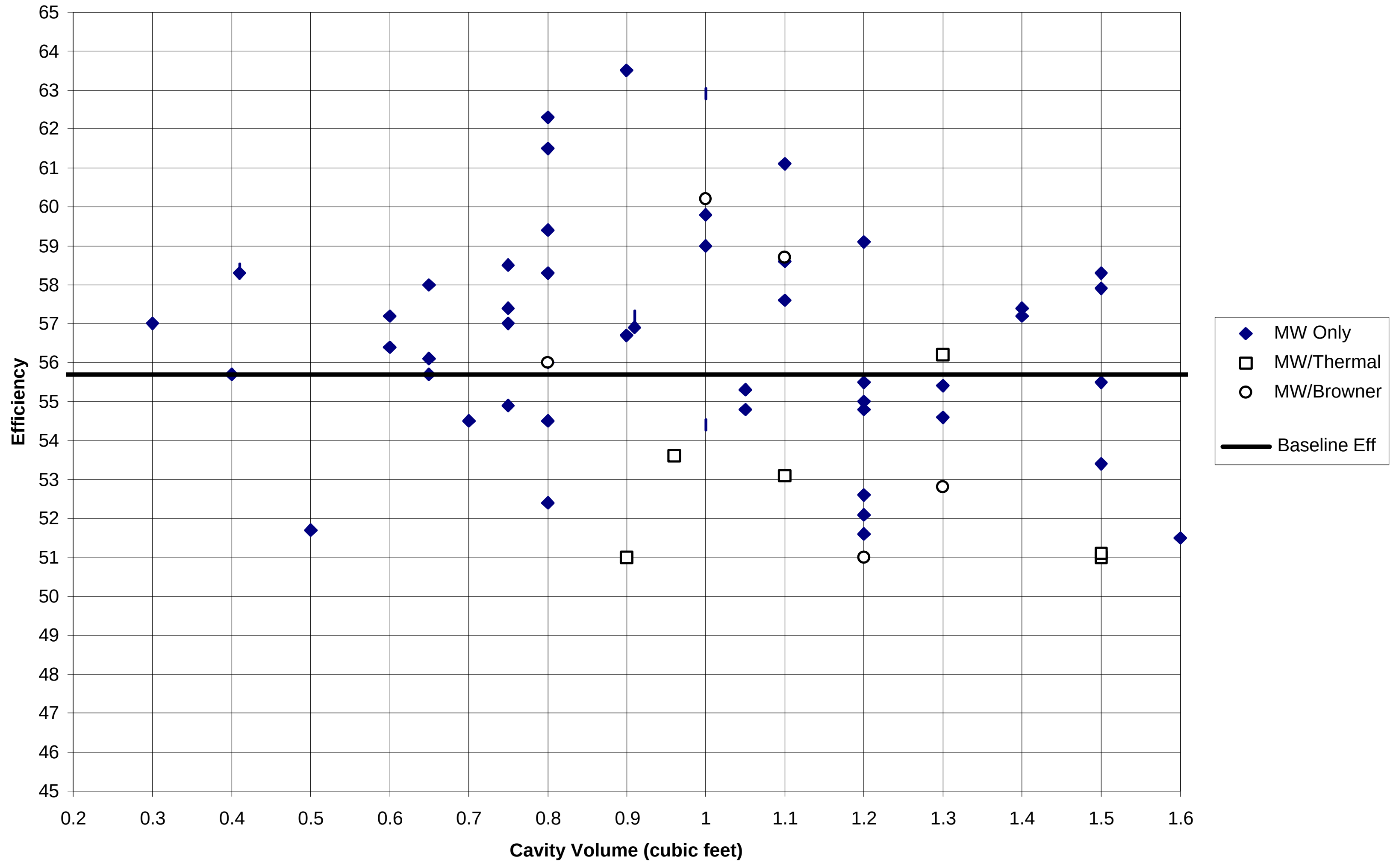

Table 1.3. Microwave Oven Capacity Volume vs. Efficiency
(Based on AHAM data of July 18, 1994 (6))

	Sample Size	Cavity Volume (ft^3) Low	Ave	Ship Wt Ave	High	One Standard Dev	Power Output[1]	Elec Pwr Input[1]	Efficiency Low	Ave	Ship Wt Ave	High	One Standard Dev
MW Type													
MW Only	52	0.30	0.95	0.95	1.60	0.32	802.80	1443.40	51.50	56.68	55.70	63.50	2.76
MW/Thermal	6	0.90	1.21	1.33	1.50	0.24	832.00	1607.40	51.00	52.67	51.80	56.20	1.90
MW/w Browner	5	0.80	1.08	1.12	1.30	0.17	853.00	1540.60	51.00	55.74	56.30	60.20	3.46
Average											54.60		
For MW Only													
<0.8 ft^3 cav vol	16	0.30	0.59	0.59	0.75	0.14	647.60	1170.60	51.70	56.50	55.30	58.40	1.70
0.8≤cav vol<1.19 ft^3	20	0.80	0.93	0.92	1.10	0.11	849.30	1474.40	52.40	58.10	57.70	63.50	3.00
≥1.2 ft^3	16	1.20	1.34	1.31	1.60	0.14	895.20	1659.10	51.50	55.10	54.00	59.10	2.30
Average											55.67		

Notes: 1. Value based on shipment weighted averages, watts

1.3 COOKTOPS

1.3.1 Design Options for Cooktops

The design options for cooktops are listed in Table 1.4. They are changes that can be incorporated into the design of a gas or electric cooktop to improve its efficiency. Some of the options are found in existing products; others are being developed.

Table 1.4 Design Options for Cooktop Product Classes

Electric Cooktops - Open (Coil) Elements
1. Improved Contact Conductance
2. Reflective Surfaces
3. Insulation
4. Electronic Controls
Electric Cooktops - Smooth Elements (Solid Disk)
1. Induction Elements
2. Halogen Elements
3. Radiant Elements
4. Electronic Controls
Gas Cooktops
1. Reduce Excess Air at Burner
2. Electronic Ignition
3. Sealed Burners
4. Reflective Surfaces
5. Insulation
6. Thermostatically Controlled Burners
7. Catalytic Burners
8. Radiant Gas Burners

Design options which attempt to improve cooktop efficiency by modulating the energy input rate to the burner or element will have no measured effect on the energy consumption under the conditions specified by the DOE test procedure. This is because the DOE test specifies the input rate to the burner or element, preventing design options such as electronic controls and thermostatic burners from having any effect on the energy consumption. These design options will still be described, but will not be analyzed for gas and electric cooktops.

As stated previously, the DOE test procedure is based on measuring the amount of energy required to raise an aluminum test block from room temperature to a specified temperature above room temperature. Of the efficiency data collected, the majority are based on tests measuring the amount of energy that is required to boil a specified amount of water. The amount of water and length of time to boiling varies depending on the researcher or manufacturer conducting the test.

Although most tests being conducted today seem to be using a "boiling water" test rather than the DOE test to measure the efficiency of cooktops, only efficiency data based on the DOE test are used in the analysis. "Boiling water" tests being conducted today do not use a standardized water load or boiling time. Until standardization takes place, data based on different "boiling water" test conditions cannot be used to judge the performance of cooktops.

The following discussion describes each design option. Comments of manufacturers on the feasibility of each design option are included. Certain design options have been eliminated which are identified in the descriptions below. Reasons for elimination have been included but the design option has been left in this TSD as a reference for any future consideration.

Improved Contact Conductance for Electric Coil Cooktops

The thermal contact resistance that arises from an imperfect contact between the cooking vessel and the open (coil) element can be reduced by improving the flatness of the element. An improved contact conductance allows for more heat to be transferred to the cooking vessel and, thus, an improvement in the efficiency of the element.

Manufacturers assert that they have worked on improving the flatness of the element and that the types that are available today are doing an excellent job. They also state that the results obtained from DOE test measurements do not reflect the actual performance of the open element. The aluminum test block used in the test procedure is much flatter than actual cooking vessels. Because of the block's very flat surface, test efficiencies will be higher than those obtained from field measurements using "real" cooking vessels. Increases in efficiency that can be obtained by improving the contact conductance under DOE test conditions will not be realized under field conditions.

All sources of available information were used in assessing the efficiency gains that could be expected from improving the contact conductance. These sources included the following: manufacturers' data provided by the Association of Home Appliance Manufacturers (AHAM), a costing analysis of design options for residential appliances prepared by ADM Associates for Lawrence Berkeley National Laboratory (LBNL) (8), and an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (9). An additional comment (10) was received from Arthur D. Little, Inc. (ADL) following the NOPR which reported the major mechanism for heat transfer was physical contact between the vessel and coil and not contact pressure. However, their results were inconclusive to support elimination of this design option. Averaging the data from these sources results in a relative efficiency increase for this design option of just over 3%.

Reflective Surfaces for Electric Coil Cooktops

This design option utilizes highly polished or chromed drip pans underneath the heating element. By reflecting some of the radiant heat of the element back up to the cooking vessel, the efficiency of the element is increased. The consumer must maintain the reflective finish by cleaning the drip pans regularly.

Manufacturers state that any increase in efficiency due to a reflective surface can easily be negated if the consumer fails to regularly clean the surface or uses an abrasive pad to clean the surface. Because of this, it would be necessary to replace reflective pans periodically at a high replacement cost.

Efficiency gains resulting from using reflective pans are extremely small. The efficiency increase was obtained from data from the following sources: manufacturers' data provided by AHAM, an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (11), and a 1980 U.S. Department of Energy Engineering Analysis for residential appliances (12). Averaging the data from these sources results in an efficiency increase of just over 1%.

Reflective pans were assumed to incur no maintenance costs. The reflectivity of the pan was assumed to be easily maintained by the consumer.

Insulation for Electric Coil Cooktops

Insulation is only used in a cooktop when it is installed as a counter top unit (not above an oven). Here, the surrounding structures encompassing the cooktop might experience surface temperature problems that can be alleviated by using insulation. The insulation is attached to the outside of the unit and could impair the cooktop's utility if it is designed to fit in an area where drawers are to be installed underneath it.

Of the published information reviewed on efficiency improvements to cooktops, adding insulation was never mentioned as a method to improve cooktop performance. Manufacturers' data provided no estimate of efficiency improvements from insulating cooktops. Because insulation seems to be used as a method to reduce surface temperatures of surrounding structures rather than as a way to increase efficiency, it was not analyzed as a design option for electric cooktops.

Electronic Controls for Electric Coil Cooktops

Electronic controls using sophisticated control algorithms can use the dynamic thermal properties of the element to turn off the energy input to the element just in time to "coast" to the desired final temperature without overshooting it.

Research has been conducted to determine the effect that electronic controls have on cooktop efficiency. Danish researchers, testing breadboard versions of microprocessor controlled electric hotplates, found a 20 to 46% energy savings in cooking a variety of foods with European recipes (13). But as mentioned previously, the DOE conditions under which cooktops are tested prevent designs that reduce energy consumption through modulation of the energy input rate from having any effect on the energy consumption. Because of this, electronic controls were not analyzed as a design option for electric cooktops.

Induction Elements for Electric Smooth Cooktops

Induction elements use a solid-state power supply to convert 60 Hz alternating house current into a high-frequency (approximately 25 kHz) alternating current. This high-frequency current is supplied to an inductor. The inductor is a flat spiral winding located just underneath a glass-ceramic panel. The high-frequency current, which is supplied to the inductor, causes it to generate a magnetic field. The magnetic field passes through the glass-ceramic panel unaffected and produces eddy currents in the bottom of the cooking vessel. The vessel must be made of some type of ferromagnetic material. The eddy currents that are generated within the vessel cause it to heat up. Thus, the vessel essentially becomes the heating element. A sensor is placed between the inductor and the glass-ceramic panel providing a continuous temperature measurement of the vessel bottom. Sensors also enable the inductor to only heat objects of at least four inches in diameter. This prevents any small metal objects, such as forks or spoons, from accidently being heated. Also, since the glass-ceramic panel is unaffected by the magnetic field, it remains relatively cool, preventing any accidental burns.

The primary advantages of induction elements are their fast response and control of the heat source, their ease of cleaning, and their ability to heat vessels that are not flat. Because these features have usually been associated with gas burners, induction elements are being marketed in competition to them.

As just noted, the cooking vessel used with an induction element must be made from a ferromagnetic material. Since aluminum is not a ferromagnetic material, the current DOE test procedure cannot be used to rate this equipment (aluminum blocks are the test load specified by the procedure to rate cooktops). In 1978, the National Bureau of Standards (NBS), now called National Institute of Standards and Technology (NIST), developed a proposed method of measuring the energy consumption of induction cooktops (14). The method is a modification of the current DOE test procedure. Energy use is determined by attaching a ferromagnetic material to the bottom of the aluminum test block. This modification was never formerly adopted by DOE. But a source was found that provided data on how a typical induction element performed under the proposed method developed by NBS (15). An absolute efficiency of 84% was presented. This information was used to determine the efficiency increase that could be expected from replacing a solid disk element with an induction element.

Halogen Elements for Electric Smooth Cooktops

Halogen elements transfer energy to the cooking vessel by direct infrared radiation from one or more high-powered tungsten-halogen lamps. The halogen element lies underneath a glass-ceramic panel and consists of one or more lamps installed horizontally within a corrosion-protected metal dish.

The bottom of the metal dish is insulated with microtherm insulation.

Radiant coils frequently are fitted into the halogen element to provide heat around the element's edge. This results in a highly responsive element that provides an even temperature distribution across the element. Halogen elements can be configured to produce a wide operating range. Parallel or series lamp arrangements can yield power outputs from 1200 to 2500 watts. Recent developments in halogen lamp technology have produced a circular lamp that can provide a more optimum temperature distribution than traditional straight lamps. This circular lamp has the trademark name of Haloring.

With the continued development of halogen elements, efficiencies have increased. The circular halogen lamp elements that have recently been developed can exceed the efficiency of solid disk elements as measured according to the DOE test procedure. Data provided by a cooktop manufacturer were used to establish the efficiency gain of a circular halogen lamp element over that of a solid disk element. An efficiency increase of approximately 1.5% was measured. It is important to reiterate that this efficiency increase is only for the circular halogen lamp element (trademark name of Haloring). Other halogen lamp elements might not yield this efficiency increase. The same cooktop manufacturer mentioned above also provided efficiency data based on boiling water tests. These tests indicated that circular halogen lamp elements can yield even higher efficiency increases over that of solid disk elements (compared to the DOE test procedure). European manufacturers have also conducted boiling water tests indicating that halogen lamp elements (the type of halogen lamp tested was not specified) are more efficient than solid disk elements (16).

Radiant Elements for Electric Smooth Cooktops

Radiant elements transfer energy to the cooking vessel by radiating heat from one or more radiant heating coils. The radiant burner lies underneath a glass-ceramic panel and consists of one or more radiant heating coils installed within a corrosion-protected metal dish. The bottom of the metal dish is insulated with microtherm insulation and the radiant heating coils are stapled to it. The side of the dish is insulated from the radiant coils by a bonded ceramic fiber wall. A temperature limiter is also installed horizontally within the burner and lies above the radiant heating coils. The limiter ensures that the glass-ceramic panel does not exceed its maximum safe temperature.

Radiant elements can be configured to a provide a wide operating range. Power ratings of typical elements range from 1000 to 2400 watts. Most manufacturers offer this burner type because it approximates the performance of the halogen element at a much lower cost. But data provided by a cooktop manufacturer indicate that standard radiant elements are less efficient than solid disk elements under the conditions specified by the DOE test procedure. An efficiency decrease of approximately 3.6% was found to exist. But new developments in radiant burner technology have yielded a supposedly more efficient radiant element that surpasses the efficiency of solid disk elements. This radiant element has the trademark name of Quick-Light. No efficiency data were obtained for this element type in time for this analysis. Although standard radiant elements (not Quick-Light) are not as efficient as solid disk elements according to the DOE test procedure, data provided by the same cooktop manufacturer mentioned above have indicated that standard radiant elements can yield a higher efficiency than solid disk elements based on boiling water tests.

Electronic Controls for Electric Smooth Cooktops

Sophisticated electronic controls can be applied to solid disk elements, radiant elements, and halogen elements to allow the element to "coast" to its final temperature. Electronic controls are not applicable to induction elements as the nature of its operation has no need for "coasting" controls. As with electric coil cooktops, electronic controls are not analyzed for smooth cooktops because the DOE test procedure will not measure the effect they have on energy consumption. For more details on electronic controls, refer to the description given for electronic controls for electric coil cooktops discussed earlier.

Reduce Excess Air at Burner for Gas Cooktops

Reducing the excess air ratio at the burner through redesign and shrouding will improve its efficiency. This information was provided by the 1980 engineering analysis performed by DOE (17) in support of developing energy efficiency standards for a variety of consumer products including cooktops and ovens. This document does not specify how the burner should be redesigned and shrouded. The Gas Research Institute (GRI) submitted a report (18) which analyzed this design option and was submitted as a comment to the NOPR. GRI concluded that the efficiency increase of this design option is not measurable at this time. They pointed out that the burner described by DOE does not exist on the market and there are no designs that can be evaluated. They also noted that use of this design option may cause a safety issue due to increased CO production. For these reasons, this design option was eliminated in the engineering analysis for gas cooktops.

Electronic Ignition for Gas Cooktops

Gas cooktops equipped without electrical power cords use a standing pilot ignition system. The energy factor of the cooktop can be increased by replacing the standing pilot system with an electronic ignition system. Actual burner efficiency is not affected by eliminating the standing pilot. The resulting increase in the energy factor is due only to the decrease in the burner's gas energy consumption.

The type of electronic ignition used by gas cooktops is an intermittent ignition system where spark ignitors replace the need for standing pilots. These ignitors are controlled by switches on each burner valve. The switches are rotary actuated so that when the burner valve is turned to the light position, a "starter" signal is sent to the control module. Once the signal is received, the control module activates the spark ignitors. The control module can either be a supervised or an unsupervised type. Supervised modules require reactivation of the burner switches for cases where burner flames are accidently extinguished. Unsupervised modules use a sensor located at the burner to sense when the flame has been accidently extinguished. The burner switches do not need to be reactivated as the sensor sends a signal back to the control module to reactivate the ignitors. Though they cost more, unsupervised ignition systems are preferred over systems that use supervised control modules as they prevent the need to check accidently extinguished flames. Most of the currently manufactured gas cooktops that are equipped with intermittent ignition systems use unsupervised control modules. Because of this, unsupervised control systems are the type of electronic ignition devices being analyzed for gas cooktops.

It is important to note that intermittent ignition systems consume negligible amounts of electricity. Since the control module is powered directly off of line voltage, there are no 24-volt transformer losses associated with it. The spark ignitor is activated for an extremely short time period so that its cumulative on-time during the course of a year, and thus its electricity consumption, is negligible.

Sealed Burners for Gas Cooktops

Unlike conventional (open) burners, the cooktop surface surrounding sealed burners butts up against the burner leaving no open area around it. This results in a reduced amount of secondary air to the burner for combustion. AHAM states that sealed burners often have a lower gas input rating than conventional burners due to the reduction in secondary air. The sealed burner must obtain all of its secondary air from air that is available above the cooktop. In order to obtain sufficient air for proper combustion, it becomes necessary to either raise the grate height or derate the burner. Contrary to these statements, a report from the 1983 International Gas Research Conference (19) states that the reduction in secondary air results in more primary aeration to the sealed burner. The increased primary aeration allows for a reduced pan-to-burner separation and an increased burner efficiency. According to the boiling water tests conducted in the report, the efficiency of conventional burners ranged from 42 to 48%, while the sealed burner was rated at an efficiency of 53%.

Manufacturers' data provided by AHAM were used to estimate the increase in efficiency due to sealed burners. An efficiency increase of approximately 2.0% was used.

Reflective Surfaces for Gas Cooktops

As with reflective surfaces for electric coil cooktops, reflective surfaces for gas cooktops also utilize highly polished or chromed drip pans underneath the burner. By reflecting some of the radiant heat of the burner back up to the cooking vessel, the efficiency of the burner is increased. The consumer must maintain the reflective finish by cleaning the drip pans regularly.

Manufacturers state that any increase in efficiency due to a reflective surface can easily be negated if the consumer fails to regularly clean the surface or uses an abrasive pad to clean the surface. Because of this, it would be necessary to replace reflective pans periodically at a high replacement cost.

Efficiency gains resulting from using reflective pans are extremely small. The efficiency increase was obtained from using manufacturers' data provided by AHAM. The data indicates that an efficiency increase of only 0.1% is realized due to the incorporation of reflective surfaces.

Reflective pans were assumed to incur no maintenance costs. The reflectivity of the pan was assumed to be easily maintained by the consumer.

Insulation for Gas Cooktops

Insulation is only used in a cooktop when it is installed as a counter top unit (not above an oven). Here, the surrounding structures encompassing the cooktop might experience surface temperature problems that can be alleviated by using insulation. The insulation is attached to the outside of the unit and could impair the cooktop's utility if it is designed to fit in an area where drawers are to be installed underneath it.

Of the information reviewed on efficiency improvements to cooktops, adding insulation was never analyzed as a method to improve cooktop performance. Manufacturers' data provided no efficiency data with regard to insulating cooktops. Because insulation seems to be used as a method to reduce surface temperatures of surrounding structures rather than as way to increase efficiency, it was not analyzed as a design option for electric cooktops.

Thermostatically Controlled Burners for Gas Cooktops

Thermostatically controlled gas burners control the gas flow to the burner through the use of a sensing element that extends through an opening in the center of the burner. This sensing element makes contact with the bottom of the cooking vessel, and thus senses the temperature and controls it. If the cooking vessel has an uneven bottom in the area where the sensor is supposed to make contact, any type of useful temperature control is lost.

Thermostatically controlled burners were widely sold in the late 1950s and 1960s. But due to customer complaints on the operating characteristics of the burner, manufacturers dropped them as a feature. Manufacturers state that the sensor's electric element retains heat due to its mass. This results in the sensor being "fooled" and causing delays in reaction time. These delays allow wide swings in the thermostatically controlled temperature. Manufacturers state that even if improvements in sensor manufacturing resulted in no heat retention, the many existing variables associated with the cooking vessel (e.g., food mass, quantity of food) make the thermostatically controlled burners' utility and energy efficiency suspect.

Though thermostatically controlled burners might reduce energy consumption, the DOE conditions under which cooktops are tested prevent designs that reduce energy consumption through modulation of the energy input rate from having any effect on the energy consumption. Because of this, no efficiency increase was associated with thermostatically controlled burners.

Radiant Gas Burners for Gas Cooktops

Radiant gas burners are a relatively recent development in gas burner technology. They are also termed powered Infrared Jet-Impingement (IR-Jet) burners. In the radiant or IR-Jet gas burner, radiant and convective energy are transmitted for cooking. A forced draft combustion fan is used to deliver the gas-air mixture to all available cooktop burners. At each burner, combustion occurs at the surface of a perforated ceramic tile. Combustion at the ceramic tile requires no secondary air. The tile is heated and glows bright red, transmitting most of its radiant energy through a glass-ceramic plate. Combustion products are jetted through the perforated glass-ceramic plate, delivering convective energy to the cooking vessel as well.

GRI has sponsored the development of the radiant (IR-Jet) gas burner. With GRI's sponsorship, the American Gas Association Laboratories (AGAL) has worked with a range manufacturer to produce a working IR-Jet burner. The IR-Jet burner is currently being marketed for commercial (restaurant-style) ranges but not for residential ranges.

Other manufacturers assert that the operating characteristics of the burner are such that it is difficult to maintain a low burner rate for many cooking functions. They state that field testing for residential ranges was discontinued because test users were unable to turn down the burner satisfactorily. Without an adequate "turn down" capability, the burner would not be able to pass the current American National Standards Institute (ANSI) standards (ANSI Z21.1).

Data collected from a boiling water test indicate that the AGAL-developed IR-Jet radiant burner is more efficient than a comparable conventional open burner. The boiling water test indicated a 16% increase in efficiency. It is not known how the IR-Jet burner would perform under DOE test conditions as the burner was never tested according to the DOE test procedure. Without the appropriate DOE test data and because the burner might not pass current ANSI standards, the IR-Jet burner was not analyzed for gas cooktops.

1.3.2 Energy Use Data for Cooktops

Unlike most appliances, an energy-labeling program has never been instituted for cooking appliances. Manufacturers are not required to report the efficiency of the cooking appliances they manufacture. Without a legal means of requiring manufacturers to report efficiency data, trade organizations representing the industry have been unable to compile directories that report the efficiencies of cooking appliance models.

Without a statistical database to select appropriate baseline efficiencies for cooktops, data from several different sources were used to determine baseline efficiencies for the three cooktop product classes. For electric coil cooktops, the following sources were originally considered during the pre-NOPR period. These include: manufacturers' data provided by AHAM, manufacturers' data provided by the Canadian Standards Association (CSA) (20), manufacturers' data obtained independently of any trade organization, a costing analysis of design options for residential appliances prepared by ADM Associates for LBL (21), an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (22), a 1980 DOE Engineering Analysis for residential appliances (23), and an appliance knowledge base prepared by Rocky Mountain Institute (24). However, during the comment period for the NOPR, ADL (25) submitted new baseline efficiency data which has been included in this analysis. Based solely on this latest ADL data, the new baseline efficiency for electric coil cooktops is 73.7% (down from 77.2% in the NOPR analysis). The cooktop was assumed to consist of two 6-inch elements and two 8-inch elements. The electrical input ratings of the 6-inch and 8-inch elements were assumed to be 1250 watts and 2100 watts, respectively.

For electric smooth cooktops, the baseline efficiency applies to a cooktop composed of four solid disk elements. The cooktop was assumed to consist of two 6-inch elements and two 8-inch elements. Most of the same sources that were used to determine a baseline efficiency for electric coil cooktops were also used to establish a baseline efficiency for electric smooth cooktops. Sources that did provide coil cooktop data, but not smooth cooktop data, were ADM and ORTECH. During the comment period for the NOPR, ADL (26) also submitted new baseline efficiency data for smooth cooktops which has been included in this analysis. Based solely on this latest ADL data, the new baseline for electric smooth cooktops is 74.2 % (up from 71.3 % in the NOPR analysis) for a 4-element electric smooth cooktop. The electrical input ratings of the 6-inch and 8-inch elements were assumed to be 1500 watts and 2000 watts, respectively.

Only manufacturers' data provided by AHAM were used to establish a baseline cooking efficiency for gas cooktops. The baseline cooking efficiency was determined to be 39.9%. The gas cooktop was assumed to consist of four conventional (open) gas burners without an electrical supply cord. Each burner was rated at 9000 Btu/h. The cooktop also consisted of two standing pilots each rated at 117 Btu/h.

An energy factor is used to rate the efficiency performance of cooktops. The energy factor is primarily a function of the cooking efficiency, and in fact, for all electric cooktops and gas cooktops equipped with an electronic ignition device, the energy factor is equal to the cooking efficiency. But for gas cooktops equipped with standing pilots, the energy factor is also a function of the gas energy consumption of the pilot lights. This results in the energy factor being significantly lower than the cooking efficiency. Eqs. 1.2 and 1.3 are provided by the DOE test procedure to calculate a gas cooktop's cooking energy consumption and energy factor, respectively. Eq. 1.4 (Eqs. 1.2 and 1.3 combined) demonstrates the relationship between a gas cooktop's efficiency and energy factor.

$$E_{CC} = O_{CT} / Eff_{CT}$$

where:

E_{CC} = Annual Cooking Energy Consumption,

O_{CT} = Annual Useful Cooking Energy Output, and
Eff_{CT} = Cooktop Efficiency.

$$R_{CT} = O_{CT} / E_{CA} \tag{1.3}$$

where:
R_{CT} = Cooktop Energy Factor,
O_{CT} = Annual Useful Cooking Energy Output, and
E_{CA} = Total Annual Energy Consumption of Cooktop = $E_{CC} + E_{PC}$.

$$R_{CT} = O_{CT} / (E_{CC} + E_{PC}) = O_{CT} / [(O_{CT} / Eff_{CT}) + E_{PC}] \tag{1.4}$$

where:
E_{PC} = Annual Energy Consumption of the Pilot Lights.

The pilot lights typically constitute up to 50% of a gas cooktop's total annual energy consumption. Therefore, a gas cooktop's energy factor is significantly lower than its efficiency. It should be noted that Eq. 1.3 is also used to determine the energy factor of electric cooktops. As evidenced from Eq. 1.3, since the electric cooktop has no miscellaneous energy consumption (e.g., pilot lights), its energy factor is equal to its cooking efficiency.

As evidenced by Eq. 1.3, the energy factor is dependent upon what value is used for the annual useful cooking energy output (O_{CT}). The existing DOE test procedure establishes an annual useful cooking energy output value of 277.7 kWh/yr and 947,500 Btu/yr for electric and gas cooktops, respectively. The existing DOE test procedure for cooking appliances, finalized in the late 1970s, established values for the annual useful cooking energy output. Manufacturers have contended that new values for the annual useful cooking energy output should be determined because cooking habits have drastically changed since the time the values for the existing test procedure were established (caused primarily by less cooking at home). Taking manufacturers' concerns into account, an analysis was performed to determine how the annual useful cooking energy output values for the existing test procedure should be amended. This analysis used a variety of electric and gas utility reports from the years 1977 through 1988 to determine updated values for the annual useful cooking energy output. These utility reports used either conditional demand analyses or metered data to establish the annual energy use of cooking appliances. Based on these utility reports, the revised annual useful cooking energy output values were determined to be 209.4 kWh/yr and 732,500 Btu/yr for electric and gas cooktops, respectively. The revised annual useful cooking energy output values were part of DOE's proposed revisions in March, 1995 to the test procedure for kitchen ranges and ovens (27). Section A.1 in Volume 2, Appendix A of this TSD provides a detailed description of the analysis that was developed to determine the revised annual useful cooking energy output values for the DOE proposed test procedure.

Based upon comments to both DOE's proposed test procedure and their proposed minimum efficiency standards for kitchen ranges and ovens, further analysis was conducted to update the values that were proposed by DOE for the annual useful cooking energy output. More recent energy usage data derived solely from metered sources (sources preceding the year 1988 were not considered) were used to establish new values for the annual useful cooking energy output. The new values were even lower than those issued by DOE in its proposed test procedure and were determined to be 173.1 kWh/yr and 527,600 Btu/yr for electric and gas cooktops, respectively. Section A.2 in Volume 2, Appendix A of this TSD provides a detailed description of the analysis that was developed to determine the annual useful cooking energy output values based on recent annual energy usage data.

Table 1.5 presents the baseline energy factors and cooking efficiencies for the three cooktop product classes. Energy factors are presented based on using annual useful cooking energy output values determined from the existing DOE test procedure, the proposed DOE test procedure, and the most recent energy usage data. As evidenced in Table 1.5, electric cooktop energy factors are identical for all three annual useful cooking energy output values. Since the energy factor is equal to the cooking energy output value it does not have any bearing on the energy factor for electric cooktops.

Table 1.5 Baseline Cooktop Energy Factors and Cooking Efficiencies

	Energy Factor			Cooking
Product Class	**Existing DOE**	**Proposed DOE**	**Recent**	**Efficiency**
Electric Coil	73.7%	73.7%	73.7%	73.7%
Electric Smooth	74.2%	74.2%	74.2%	74.2%
Gas	21.4%	18.8%	15.6%	39.9%

In the previous section on design options, information was presented on how each design option impacted the cooking efficiency. Increases in cooking efficiency as a result of incorporating prospective design options were either expressed as a relative percentage increase or an absolute percentage point increase. These are indicated in the "Notes" under each Cost-Efficiency table (Tables 1.6 through 1.8) as either "relative percent" or "absolute percentage points", respectively.

In the case of electric cooktops, both coil and smooth types, the cooking efficiency is equal to the energy factor. The results of the energy-efficiency analysis are presented in Tables 1.6 and 1.7 for coil and smooth cooktops, respectively. For each design option, the efficiency (*Eff*), the energy factor (*EF*), and the annual energy consumption (E_{CA}) of the cooktop are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of electric cooktops, two annual energy consumptions are presented in each Table; one is based on the annual useful cooking energy output from the proposed DOE test procedure (209.4 kWh/yr) and the other is based on using the value from the more recent energy usage data (173.1 kWh/yr). Annual energy consumption values based on the existing DOE test procedure are not provided in Tables 1.6 and 1.7 because the existing test procedure's annual useful cooking energy output values are out of date. Referring back to Eq. 1.2, the annual cooking energy consumption is calculated by dividing the annual useful cooking energy output by the cooktop's cooking efficiency. Also included in Tables 1.6 and 1.7 are the total manufacturing costs for each design option. These costs will be explained in the following section (Cost-Efficiency Data).

Table 1.6 Cost-Efficiency Table for Electric Coil Cooktops

Energy Efficiency Level	Design No.	Design Option	Mfg. Cost *1990$*	Eff %	EF *%*	Proposed[4] E_{CA} *kWh*/yr	Recent[5] E_{CA} *kWh*/yr
1	0	Baseline[1]	69.06	73.7	73.7	284.0	234.7
2,3	1	0 + Impr. Contact Conductance[2]	71.34	76.9	76.9	272.4	225.2
4,5	2	1 + Reflective Surfaces[3]	74.37	77.7	77.7	269.6	222.9

Notes:
(1) Baseline: Cooktop Cooking Eff. = 73.7 %; two 6-inch (1250 watt) and two 8-inch (2100 watt) elements
(2) Improved Contact Conductance: Cooking Efficiency increase = 4.3% (relative percent)
(3) Reflective Surfaces: Cooking Efficiency increase = 1.0% (relative percent)
(4) "Proposed" E_{CA} based on proposed DOE test procedure annual useful cooking energy output of 209.4 kWh/yr
(5) "Recent" E_{CA} based on recent energy usage data yielding an annual useful cooking energy output of 173.1 kWh/yr

Table 1.7 Cost-Efficiency Table for Electric Smooth Cooktops

Energy Efficiency Level	Design No.	Design Option	Mfg. Cost *1990$*	Eff *%*	EF *%*	Proposed[5] E_{CA} *kWh/yr*	Recent[6] E_{CA} *kWh/yr*
1,2,3,4	0	Baseline[1]	89.14	74.2	74.2	282.3	233.4
	1	0 + Halogen Lamp Element[2]	255.12	75.3	75.3	278.0	229.8
5	2	0 + Induction Element [3]	370.74	84.0	84.0	249.3	206.4
	3	0 + Radiant Element[4]	137.28	71.5	71.5	292.9	242.2

Notes:
(1) Baseline: Cooktop Cooking Eff.= 74.2%; two 6-inch (1500 watt) and two 8-inch (2000 watt) solid disk elements
(2) Halogen: Cooking Eff. increase = 1.5% (relative percent); two small (1200 watt) and two large (1800 watt) circular lamps
(3) Induction: Cooktop Cooking Eff. = 84.0% (absolute percentage points)
(4) Radiant: Cooking Eff. decrease = 3.6% (relative percent) ; two small (1200 watt) and two large (1700 watt) radiant elements
(4) "Proposed" E_{CA} based on proposed DOE test procedure annual useful cooking energy output of 209.4 kWh/yr
(5) "Recent" E_{CA} based on recent energy usage data yielding an annual useful cooking energy output of 173.1 kWh/yr

As stated earlier, for gas cooktops using a standing pilot ignition system, the energy factor is not equal to the cooking efficiency. As presented in Eq. 1.3, the total annual energy consumption is equal to the annual cooking energy consumption plus the annual pilot energy consumption. The annual pilot energy consumption is calculated by using Eq. 1.5.

$$E_{PC} = P \bullet A \qquad \textbf{(1.5)}$$

where: E_{PC} = Annual Energy Consumption of any Continuously Burning Gas Pilot,
P = Pilot Light Input Rate (Btu/hr), and

A = Total Number of Hours in a Year = 8760 hours.

The baseline gas cooktop is assumed to have two standing pilots each rated at 117 Btu/hr. This represents an annual pilot energy consumption of 2050 kBtu.

The results of the energy efficiency analysis for gas cooktops are presented in Table 1.8. For each design option, the efficiency (*Eff*), the annual cooking energy consumption (E_{CC}), the annual pilot energy consumption (E_{PC}), the total annual energy consumption (E_{CA}), and the energy factor (*EF*) are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of gas cooktops, two sets of values are presented for the total annual energy consumption and the energy factor. One set of values is based on using the annual useful cooking energy output from the proposed DOE test procedure (732,500 Btu/yr) and the other set is based on using the value from the more recent energy usage data (527,600 Btu/yr). Even though the annual cooking energy consumption is also affected by the annual useful cooking energy output, only the value based on the proposed DOE test procedure is provided. The annual cooking energy consumption based on more recent energy usage data is determined simply by multiplying the proposed test procedure's value by the ratio of the "recent"-to-"proposed" annual useful cooking energy output values (527,600 to 732,500 Btu/yr). Annual energy consumption and energy factor values based on the existing DOE test procedure are not provided in Table 1.8 because the existing test procedure's annual useful cooking energy output values are out of date. Referring back to Eq. 1.2, the annual cooking energy consumption is calculated by dividing the annual useful cooking energy output by the cooktop's cooking efficiency. The total annual energy consumption is the sum of the annual cooking energy consumption and the annual pilot energy consumption (the annual pilot energy consumption is calculated from Eq. 1.5). Referring back to Eq. 1.3, the energy factor is calculated by dividing the annual useful cooking energy output by the total annual energy consumption. Also included in Table 1.8 are the total manufacturing costs for each design option. These costs will be explained in the next section (Cost-Efficiency Data).

The design options listed in Tables 1.6 through 1.8 are ordered so that those that are easiest to carry out and that are relatively more cost-effective are listed first. For electric smooth cooktops, none of the design options listed Table 1.7, i.e., halogen, induction, and radiant elements, have a low manufacturing cost. Due to the resulting high costs of the design options, the probability that any of them will be cost-effective is low.

The three cooktop product classes each have a unique maximum technologically feasible design. For electric coil cooktops, the "max tech" design incorporates both reflective surfaces and improved coils that increase the contact conductance between the cooking load and the coil surface. Based on the "most recent" annual useful cooking energy output value, the minimum energy use is 222.9 kWh/year. For electric smooth cooktops, the "max tech" design is a cooktop consisting of four induction elements. Its minimum technologically feasible energy use based on the "most recent" annual useful cooking energy output value is 242.2 kWh/year. For gas cooktops, the "max tech" design consists of four thermostatically controlled sealed burners, which incorporate reflective surfaces and electronic ignition. Its minimum technologically feasible energy use is 1256 kBtu/year when the "most recent" value for the annual useful cooking energy output is used.

Table 1.8 Cost-Efficiency Table for Gas Cooktops

Energy Efficiency Level	Design No.	Design Option	Mfg. Cost *1990 $*	Eff *%*	E_{PC} *kBtu*	Proposed[6] E_{CC}[8] *kBtu*	Proposed[6] E_{CA} *kBtu*	Proposed[6] EF *%*	Recent[7] E_{CA} *kBtu*	Recent[7] EF *%*
1,2	0	Baseline[1]	89.09	39.9	2050	1837	3887	18.8	3373	15.6
3,4	1	0 + Electronic Ignition[2]	101.15	39.9	0	1837	1837	39.9	1323	39.9
	2	1 + Sealed Burners[3]	121.15	42.0	0	1746	1746	42.0	1257	42.0
5	3	2 + Reflective Surfaces[4]	127.29	42.0	0	1744	1744	42.0	1256	42.0
	4	3 + Thermostatic Burners[5]	144.22	42.0	0	1744	1744	42.0	1256	42.0

Notes:
(1) Baseline: Cooktop Cooking Eff. = 39.9%; four conventional 9000 Btu/hr burners, two 117 Btu/hr standing pilots
(2) Electronic Ignition: Eliminate Standing Pilots, Cooking Efficiency increase = 0.0%
(3) Sealed Burners: Cooking Efficiency increase = 4.8% (relative percent)
(4) Reflective Surfaces: Cooking Efficiency increase = 0.1% (relative percent)
(5) Thermostatically Controlled Burners: Cooking Efficiency increase = 0.0%
(6) "Proposed" E_{CA} and EF based on proposed DOE test procedure annual useful cooking energy output of 732,500 Btu/yr
(7) "Recent" E_{CA} and EF based on recent energy usage data yielding an annual useful cooking energy output of 527,600 Btu/yr
(8) "Recent" E_{CC} is determined by the following calculation: $E_{CC\ RECENT} = E_{CC\ PROPOSED} \bullet (527{,}600 / 732{,}500)$

1.3.3 Cost and Efficiency Data for Cooktops

In this section, cost and efficiency data are discussed for the three cooktop product classes. The cost data consist of manufacturer, maintenance, and installation costs. The manufacturer cost is the cost to the manufacturer of producing products with the design options shown and does not include markups to wholesalers or retailers.

The maintenance cost is annualized over the lifetime of the product and is incorporated as an operating cost to the consumer of maintaining the operation of the cooktop. The only design option that incurs a maintenance cost is the electronic ignition system for gas cooktops. All other design options, for both electric and gas cooktops, were assumed not to increase the cost of maintaining the operation of the cooktop. The maintenance cost consists of replacement parts and labor. In order to estimate the maintenance cost of electronic ignition devices, a retirement function was constructed for two of the device's components: the control module and the sensor. All other electronic ignition components were assumed to last the lifetime of the appliance. The lifetime of both gas and electric cooktops was assumed to be 19 years (28). The retirement function is a curve of component lifetime versus the year of component failure. The function was constructed from information provided by electronic ignition manufacturers. For more details regarding the development of this maintenance cost, please refer to Appendix D in the General Methodology Volume (Volume 1) of this TSD.

The installation cost is the added first cost of having a contractor or appliance service person install the cooktop in a home. It does not include the retail cost of the cooktop. For electric cooktops, design options were assumed not to increase the installation cost of the cooktop.

For gas cooktops a cost of $90.00 would be incurred for every house requiring the installation of an electrical outlet. An assumption was made that 25% of the cooktop purchases would require this installation cost. This value represents an estimate of how many homes would need an electrical outlet if a pilotless ignition cooktop or oven were installed. Therefore a value of $22.50, or 25% of $90.00, was used in the cost analysis to account for this installation cost. GRI made estimates of 0, 25, and 50% in their analysis; however they stated "the proportion of installations needing a grounded electrical outlet is unknown" (29). They based a 50% estimate on AHAM's data which reports 23.4% of all gas ranges and 8.3% of gas cooktops shipped in 1993 had gas-piloted ignitions. GRI argued "this indicates that a significant portion of the range replacement market would require new or updated electrical outlet installation". However, this conclusion is unsupportable. Shipment weighted averages for products shipped with/without pilots are merely an indicator that some (maybe a small) percentage of homes <u>may</u> not have an electrical outlet available. In fact, of these homes, some may have an electrical outlet available, but the homeowners simply do not want a pilotless ignition, or merely purchases a piloted unit because it is less expensive than one with an electronic ignition. Therefore, there is no direct link between the percentage of range/cooktops shipped with pilots and installations that need an electrical outlet. However, for analysis sake, the present analysis assumed a conservative estimate of 25%. This estimate is supported by a recent change in the National Electrical Code which will affect kitchens in the future. According to the National Electrical Code (1993 Edition, Sections 210-50(c), 210-52, and 220-4(b)), receptacle outlets are <u>required</u> in every kitchen. In fact the Code specifically refers to "Receptacles installed to provide power for electric ignition systems or clock timers for gas-fired ranges, ovens, or counter-mounted cooking units" as being allowed to have more than one outlet on the circuit, probably because of the low power draw. The only Code item mentioned in the GRI Topical Report was the requirement that appliance receptacle outlets be installed within 6 feet of the intended location of the appliance. This seems to be a moot point. The code already requires that the outlets be installed in the kitchen or else it (the kitchen), is not up to code. It should be noted that the code requirement specifically addressing "electric ignition systems...for gas-fired ranges, ovens..." was established in 1993. Therefore, some fraction of homes prior to this date are not required to have these receptacle outlets, and therefore would need one if a pilot-less product was used, thus incurring an installation cost. But, this fraction of homes would decrease over the time period from 2000 to 2030 in which the cost-benefit analysis is computed.

The cost and efficiency data were combined and are presented in Tables 1.6 to 1.8. These tables were presented in the previous section on Energy Use Data (Section 1.3.2). Appendix A, Section A.3 herein contains disaggregated manufacturer's costs for the three product classes. Total manufacturer costs are divided into material, labor, tooling, shipping, and indirect costs. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. Several sources were used in establishing the costs. AHAM supplied manufacturers' cost estimates for the following design options: reflective surfaces for both electric coil and gas cooktops, thermostatically controlled burners for gas cooktops, and increased contact conductance for electric coil cooktops. Independent of any trade organization, a few cooktop manufacturers provided manufacturers' cost data for the following design options: halogen lamp elements and radiant elements for electric smooth cooktops. Estimates of manufacturers' costs were obtained from suppliers for the following design options: electronic ignition devices for gas cooktops, and halogen lamp elements and radiant elements for electric smooth cooktops. A 1980 U.S. Department of Energy Engineering Analysis for residential appliances (30) was used to estimate the cost of reducing the excess air at gas cooktop burners and to estimate the cost of reflective surfaces for electric coil cooktops. A report by ADM Associates for LBNL (31) was used to help estimate the cost of increasing the contact conductance in electric coil cooktops. An appliance knowledge base prepared by Rocky Mountain Institute (32) was used to estimate the cost of induction elements for electric smooth cooktops. A research organization familiar with the development of cooking appliances provided estimates of the cost to incorporate sealed burners into gas cooktops. Also, additional data was incorporated from many sources as a result of written/oral comments to the NOPR which are appropriately referenced in this TSD.

1.3.4 Maximum Technologically Feasible Design

The maximum technologically feasible designs for the three cooktop product classes were previously discussed in the Energy-Use Data section. For electric coil cooktops, the “max tech” design incorporates both reflective surfaces and improved coils that increase the contact conductance between the cooking load and the coil surface. For electric smooth cooktops, the “max tech” design is a cooktop consisting of four induction elements. For gas cooktops, the “max tech” design consists of four sealed burners that incorporate reflective surfaces and electronic ignition. The efficiency of the "max tech" design was derived from data given by manufacturers plus a variety of other sources. All of the efficiency values (and manufacturing costs as well) in Tables 1.6 through 1.8 have some uncertainty associated with them.

For the three cooktop product classes, the range of the 95% confidence interval varies for each of the maximum technologically feasible designs. The low end of the 95% confidence interval for the electric coil cooktop product class is 2.0% lower than the "max tech" design's energy factor while the high end of the interval is 2.1% higher than the "max tech" design's energy factor. For the electric smooth cooktop product class, the low and high ends of the 95% confidence interval are 6.3% lower and 6.1% higher than the "max tech" design's energy factor. For the gas cooktop product class, the low and high ends of the 95% confidence interval are 0.4% lower and 0.7% higher than the "max tech" design's energy factor. Volume 1, Appendix A of this TSD provides a general discussion of how the 95% confidence interval is established for "max tech" designs.

1.4 OVENS

1.4.1 Design Options for Ovens

The design options for ovens are listed in Table 1.9. They are changes that can be incorporated into the design of a gas or electric oven to improve its efficiency. Some of the options are found in existing products; others are being developed.

Table 1.9 Design Options for Ovens

1. No Oven Door Window
2. Improved Insulation
3. Added Insulation
4. Reduced Vent Rate
5. Reduced Conduction Losses
6. Use of Reflective Surfaces
7. Reduction of Thermal Mass
8. Forced Convection
9. Oven Separator
10. Improved Door Seals
11. Steam Cooking
12. Bi-Radiant Oven (Electric Ovens only)
13. Halogen Lamp Oven (Electric Ovens only)
14. Pilotless Ignition (Gas Ovens only)
15. Radiant Burner (Gas Ovens only)

The following discussion describes each design option. Comments of manufacturers on the feasibility of each design option are included.

No Oven Door Window

Most ovens and ranges come equipped with windows in the door. With the window, the contents of the oven can be viewed without opening the oven door. But oven door windows allow more energy to be lost through the door and thus, reduce the efficiency of the oven. It could be argued that having no window in the door necessitates frequent door openings to check the contents of the oven. The lost energy caused by these door openings could offset any energy savings that would result from eliminating the door window.

GRI issued a topical report (33) which discussed this design option. The report was submitted as a written comment to the NOPR. GRI's experimental tests showed a small savings in annual energy usage (increase in efficiency) for both the standard and self-clean ovens. However, they report there could actually be a net energy loss due to consumer practices, which would be a function of the number of times a consumer would open the door to inspect the food while cooking. With 4 door openings per test (DOE test procedure), a standard oven would realize a net energy savings of 34 kBtu/yr and an annualized net savings of $0.24. For a self-clean oven there is a net energy loss of 3 kBtu/yr with an annualized net increase in cost of $0.02. The report also stated there would be reduced consumer utility and the possibility of failure of delicate food items (souffles) without the window. There were also comments about decreased safety without the window due to increased risk of burns from additional door openings while the oven is in use. For these reasons, this design option was not analyzed.

Improved and Added Insulation

The efficiency of an oven can be increased by either improving the insulation or adding more insulation to the cabinet walls and oven door. Most models can accommodate 4 inches of insulation in the cabinet walls and door without requiring extensive design changes to the oven. Most non-self-cleaning models have 2 inches of low-density (1.09 lb/ft^3) fiberglass insulation in the cabinet walls and door, while most self-cleaning ovens use 2 inches of high density (1.90 lb/ft^3) insulation. Data found in published papers and reports indicate that fiberglass insulation density levels do not exceed those found in self-cleaning ovens (1.90 lb/ft^3). Thus, while both the thickness and density of the insulation can be increased in most models of non-self-cleaning ovens, only the thickness can be increased in most self-cleaning ovens.

Since the DOE test procedure does not require maintaining heat in the oven over a period of time, manufacturers state that increasing the thickness or density of the oven's insulation will demonstrate no energy savings. But data provided by several sources indicate that small energy savings can be realized under the conditions of the DOE test procedure.

The following sources were used to establish the efficiency increase from using a denser insulation (1.09 to 1.90 lb/ft^3): manufacturers' data provided by AHAM, a costing analysis of design options for residential appliances prepared by ADM Associates for LBNL (34), an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (35), and the 1980 DOE Engineering Analysis for residential appliances (36). Averaging the data from these sources results in an efficiency increase of 4.9% for standard gas ovens and a 5.2% increase for standard electric ovens.

Two sources of data were available which showed an increase in efficiency due to adding more insulation (2 to 4 inches): manufacturers' data provided by AHAM and the 1980 DOE Engineering Analysis for residential appliances (37). Averaging these data results in an absolute percentage point increase of approximately 1.4. However, GRI (38) reported no change in energy consumption by adding insulation. They also showed an increase in cost to the consumer with a decrease in consumer utility since the oven cavity volume would have to be reduced to maintain the same oven footprint. The reduced oven cavity volume would limit the size of large items which could be cooked in the oven. For these reasons, added insulation was not analyzed. However, improved insulation (the standardization in oven insulation density for both non-self-cleaning and self-cleaning to 1.90 lb/cu ft) has been analyzed.

Reduced Vent Rate

Oven vent tubes function primarily to remove the moisture present during the baking process. Self-cleaning ovens have reduced vent diameters to limit the air flow in accordance with combustion safety regulations during the high-temperature cleaning cycle. For safety reasons, the vent rate found in self-cleaning ovens cannot be reduced any further. But the vent rate of standard ovens can be reduced to the rate of self-cleaning ovens. This can be accomplished by either reducing the vent tube size or adding a baffle. A reduction in vent rate causes a corresponding increase in efficiency.

Manufacturers state that reduced vent rates should only be considered for standard electric ovens. The vent diameters of standard and self-cleaning gas ovens are not significantly different as both oven types need to maintain a satisfactory combustion environment. With regard to standard electric ovens, manufacturers assert that vent sizes are unique to the design of the oven. The vent size is critical in maintaining the oven's proper cooking and safety performance. Mandating a specific vent rate would require most oven models to be redesigned in order to maintain their proper performance.

But manufacturers' data provided by AHAM indicates that the vent size of both standard electric and standard gas ovens can be reduced. Since all self-cleaning ovens are already designed with this technology, no new improvements, or prototypes are required by the industry to incorporate this design option. Averaging the manufacturers' data with data obtained from a costing analysis of design options for residential appliances prepared by ADM Associates for LBNL (39) results in an absolute percentage increase of approximately 0.62 percentage points for standard electric ovens and 0.5 percentage points for standard gas ovens.

Reduced Conduction Losses

Conduction losses from the oven can be reduced by upgrading the oven door. This upgrade includes an additional thermal break and a modified inner panel. Manufacturers state that with existing instrumentation, the DOE test procedure cannot measure the small energy gains that can be obtained by attempting to reduce conduction losses.

Manufacturers' data provided by AHAM indicate that a very small efficiency increase is possible. The data indicate that only a percentage point increase of 0.05 is expected from reducing conduction losses. No other data were obtained to demonstrate whether the efficiency increase should be any higher or lower.

Use of Reflective Surfaces

Oven efficiency can be improved by incorporating reflective surfaces onto the walls of the oven cavity. Reflective surfaces improve the oven's performance by reflecting and retaining infrared radiation within the oven cavity, thus increasing the percentage of useful heat.

Manufacturers state that is has been very difficult to obtain satisfactory cooking performance with reflective surfaces. The reflective materials degrade after the first baking function and continue to degrade through the life of the product. This is especially true of self-cleaning ovens as the self-cleaning process damages the reflective walls and negates any possible energy savings.

GRI (40) performed tests on this design option which resulted in a decrease in energy efficiency. The reflective surface interfered with the convective currents and the thermostat, thus fooling the thermostat into cycling. They report that increased reflectance from the chrome-plated inner surface of the oven caused repeated thermostat cycling, that "might have contributed to the higher energy consumption" which resulted in a 12.61 percent decrease in energy efficiency. ADL (41) also commented that the reflected radiation is different from the normal radiation emitted by the current oven cavities in use today.

Based on these recent studies, it is uncertain whether, or how much, energy savings is realizable with this design option. A smarter controller for the oven seems to be a reasonable fix for the problem. However, there is a general lack of sophistication in the technology to maintain clean, reflective surfaces over the lifetime of the product. For these reasons, this design option was not analyzed.

Reduction of Thermal Mass

Energy is absorbed by the oven components as the oven warms to its operating temperature. By reducing the amount of material used in constructing the oven, the amount of energy that is absorbed is reduced and hence the efficiency increases. One method of achieving this thermal mass reduction is to reduce the gauge of sheet metal used in constructing the oven. Manufacturers assert that this type of thermal mass reduction is not possible for currently manufactured electric and gas ovens. They state that the oven walls must provide strong enough support to hold racks when baking heavy items (i.e., turkeys, large roasts). Present oven metal gauges cannot be reduced any further without risking cracking and greater heat losses.

Several sources of data indicated that a 10% to 20% reduction in thermal mass is possible. The sources which state that an efficiency increase from reducing the thermal mass was possible included the following: manufacturers' data provided by AHAM, a costing analysis of design options for residential appliances prepared by ADM Associates for LBNL (42), and an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (43). GRI (44) tests showed only a 0.58% efficiency improvement for a self-cleaning oven with an equivalent of 5.52 pounds of wall material removed. However, issues of structural integrity during use and transportation, and also the issue of consumer product safety are important factors. Because of these factors, this design option was not analyzed.

Forced Convection

A forced convection oven uses a fan to distribute warm air evenly throughout the oven cavity. The use of forced circulation can reduce fuel consumption by cooking food more quickly, at lower temperatures, and in larger quantities than a natural convection oven of the same size and rating. The fan is placed within the rear cabinet wall and a protective screen is placed around it. The screen prevents any items being placed in the oven from "knocking" into it and causing damage.

Currently, only a few U.S. manufacturers are manufacturing and selling electric convection ovens. An operating manual provided by one of these manufacturers indicates that cooking times can be reduced by using forced convection cooking. No manufacturer has yet offered forced convection cooking for gas ovens. But GRI has sponsored the development of two new types of gas ovens that incorporate forced convection cooking. Both oven types, one an advanced counter top oven and the other an advanced full-size oven with pyrolytic self-cleaning, also have steam-cooking options. The actual research and development of the ovens is being conducted at ADL. Of the two oven types, development of the counter top oven is farther along. Test results indicate that counter top oven cooking times are as fast as those found in microwave ovens (45).

Manufacturers state that convection ovens should be made a separate product class due to their unique operating characteristics (i.e., forced circulation). But as stated previously in the section on Product Classes, forced convection is being considered as a design option rather than a product class. Although forced convection cooking offers the additional consumer utility of faster cooking, it does not warrant its addition as a separate class.

Estimates from manufacturers, researchers, and published reports (e.g., energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (46)) were included in the analysis to establish the efficiency increase due to forced convection. Averaging these estimates results in a relative efficiency increase of 23% for gas self-cleaning ovens using forced convection cooking. For gas standard ovens a value of 4.8% was used based on more recent GRI data (47). Additional data submitted during the NOPR comment period by ADL (48) shows an increase in efficiency for electric convection ovens of only 2.4% or 0.33 percent points. More testing is needed to validate the efficiency improvements associated with this design option, especially with regard to the large difference in efficiency improvement between gas self-cleaning ovens and all others.

It is also important to consider the added electrical energy consumption of the convection fan when determining the energy factor for ovens incorporating convection cooking. The wattage of a typical convection fan motor is approximately 30 watts. Since the duration of the DOE test procedure is approximately 30 minutes, the energy consumption of the convection fan is approximately 15 watt-hours.

Oven Separator

For loads that do not require the entire oven volume, an oven separator can be used to reduce the cavity volume that is used for cooking. With less oven volume to heat, the energy used to cook an item would be reduced. The oven separator considered here is the type that can be easily and quickly installed by the user. The side walls of the oven cavity would be fitted with "slots" that guide and hold the separator into position. Different pairs of "slots" would be spaced through out the oven cavity so that the user could select different positions to place the separator. Ovens incorporating separators are currently manufactured by the German company AEG. In their promotional literature they advertise energy savings of up to 20%.

U.S. manufacturers state that the use of an oven separator has been researched but has never been put into production because of problems it would cause both manufacturers and consumers. With regard to conventional gas ovens, manufacturers state that the separator cannot be economically designed for improved efficiency, though an acceptable design for gas convection ovens might be possible. With regard to electric ovens, manufacturers assert that the separator would require the installation of an additional element and a non-conventional oven-control system. Manufacturers also state that it would be difficult to obtain UL and American Gas Association (AGA) approvals and meet existing ANSI standards because of the effect the separator would have on safety and performance. Manufacturers also state that consumer acceptance would probably be low because appliances such as microwave and toaster ovens already exist to cook small loads. In addition, the separator would have to be designed to be "fool-proof" to prevent consumers from accidently installing it incorrectly. With regard to energy use, the additional metal added to the oven by the separator (increased thermal mass) might result in increased energy losses.

Manufacturers' data provided by AHAM indicates that a percentage point increase of approximately 0.82 is expected from using an oven separator in standard and self-cleaning electric ovens. For standard and self-cleaning gas ovens, percentage point increases of 0.1 and 0.53 are expected, respectively. No other data were provided to demonstrate whether the efficiency increase should be any higher or lower.

Improved Door Seals

Door seals for standard ovens generally consist of a strip of silicone rubber while self-cleaning ovens usually incorporate fiberglass seals. These seals are attached to the oven front frame and act as a seal for the door, which serves to reduce the loss of hot oven air through the door. Because some venting is required for proper cooking performance, a complete seal on the oven is undesirable. But the oven door seals can be improved further without sealing the oven completely.

Data from an energy-efficient electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (49) estimates the efficiency increase from improving the door seals. The data indicated that an approximately 7% increase in efficiency was possible for standard electric ovens and both standard and self-cleaning gas ovens. However, more recent data by GRI (50) show efficiency increases much less than the 7% value previously reported. A value of 1% was used for the standard and self-cleaning gas oven analysis. The GRI report also pointed out the need for sufficient air flow though the oven cavity for proper heating and moisture conditions while cooking. This concern was considered in the analysis. This design option assumes proper air flow is maintained.

Steam Cooking

A German manufacturer has developed an oven that incorporates steam cooking into an electric convection oven (51). By injecting very low pressure steam into the oven cavity, the cooking time can be reduced. Though the steam is essentially pressureless, a "steam-tight" oven cavity must be maintained to ensure that none escapes. In addition, the use of steam involves considerably higher demands on the oven's design and materials. Not only are new cavity materials required (e.g., temperature-resistant silicone seals and chrome nickel steel), but all incorporated elements and accessories have to be redesigned and intensively tested. Though incorporating steam cooking into oven designs is a difficult task, the manufacturer claims that there are advantages to using steam over conventional methods of cooking. Those advantages include saved energy and being able to retain more of the food's nutritional value. Energy is saved because food items that normally would need to be cooked separately (e.g., a meat roast in an oven and vegetables on a cooktop) can now be cooked together using the steam cooking process.

As mentioned earlier under the discussion of the forced convection design option, GRI has sponsored the development of two new types of gas ovens that incorporate forced convection and steam cooking. One of the oven types is an advanced counter top oven, while the other is an advanced full-size oven with pyrolytic self-cleaning. Of these two oven types, development of the counter top oven is farther along. Test results indicate that counter top oven cooking times are as fast as those found in microwave ovens (52).

Though there has been activity in the development of residential steam cooking, no domestic manufacturer is currently producing this type of oven. Manufacturers state that the steam oven should be made a separate product class rather than be considered a design option to improve the efficiency of conventional ovens. Although steam cooking might offer the additional consumer utility of more nutritional cooking, it does not warrant its addition as a separate class.

Because steam ovens have recently been developed, no data have been presented to establish whether they are more efficient than conventional ovens. Because no efficiency data are available, this design option was not analyzed for either electric or gas ovens.

Pilotless Ignition (Gas Ovens Only)

Gas ovens equipped without electrical power cords use a standing pilot ignition system. The energy factor of the oven can be increased by replacing the standing pilot system with an electric or electronic ignition system. Actual oven efficiency is only slightly affected by eliminating the standing pilot. The resulting increase in the energy factor is due only to the decrease in the oven's gas energy consumption.

There are two types of pilotless ignition systems for gas ovens: a spark ignition system and a "glo" ignition system. The spark ignition system uses a spark ignitor to light a pilot. The pilot in turn ignites the oven burner. The ignitor is controlled by a control module, which is activated when the thermostat knob is set to a specific temperature. The ignitor will spark until the pilot is ignited, and the pilot will burn until the thermostat is turned off. If the pilot should accidently be extinguished, a sensing circuit within the ignitor will reactivate the control module and cause the ignitor to spark. The spark ignition system consumes a negligible amount of electricity. Since the control module is powered directly off of line voltage, there are no 24-volt transformer losses associated with it. The spark ignitor is activated for an extremely short time so that its cumulative on-time during the course of a year, and thus its electricity consumption, is negligible.

The "glo" ignition system uses a carbide "glo" type ignitor. When the thermostat is set to a specific temperature, voltage (120 volts) is applied to the ignitor. Once energized, the ignitor draws 3.2 amps and heats to a high temperature. In series with the ignitor is a safety valve that is electrically activated. Once the ignitor draws 2.9 amps, the safety valve opens allowing gas to flow to the oven burner. The hot "glo" ignitor then ignites the oven burner. Because the safety valve remains open only when the "glo" ignitor is drawing 2.9 amps, the ignitor must continually draw power (~384 to 432 watts) to keep the burner ignited (53). Thus the electrical energy consumption of a "glo" ignition system is significant and must be accounted for when analyzing it as a substitute for standing pilot ignition systems. There are other types of ignitors which draw less wattage which are called "mini" hot surface ignitors (HSI). Typical mini-HSIs draw about 50 watts and one is reported to operate at 24 watts. However, these low-wattage ignitors only draw 2.1 amps (at 24 volts), and therefore are below the 2.9 amps needed to open the safety valve. A change in design of the control systems is required to incorporate these mini-HSIs into cooking oven products.

In the analysis of pilotless ignition systems for gas ovens, "glo" type (120 volt) and electronic ignition systems were considered.

Radiant Burner (Gas Ovens Only)

Though gas cooktops are currently being manufactured with radiant gas burners (refer to the discussion of design options for gas cooktops), no known prototype has been built using radiant burners in gas ovens. Manufacturers have commented that this technology is available for gas ovens, but no information has been provided to indicate exactly how it would be incorporated into an oven design. It is assumed that the type of radiant burner used in a gas oven would be similar to those currently used in gas cooktops. A forced draft combustion fan would be used to deliver a gas-air mixture to the burner. Radiant and convective energy would then be transmitted to the oven cavity by the burner.

Since no data were either provided or found to demonstrate whether radiant gas burners can perform effectively and efficiently in gas ovens, they were not analyzed as a design option for gas ovens.

Bi-Radiant Oven (Electric Ovens Only)

A bi-radiant electric oven system was developed by Purdue University for Oak Ridge National Laboratory in the late 1970s (54). The objective of the project was to develop an electric oven that offered significant energy savings without compromising food quality. The bi-radiant oven has three important features which provide improved performance. First, the cavity walls are highly reflective rather than absorptive thereby allowing these surfaces to operate at cooler temperatures. Second, the heating elements, similar in construction to those in conventional ovens but operating at much lower temperatures, provide a prescribed, balanced radiant flux to the top and bottom surfaces of the food product. And third, the baking and roasting utensil has a highly absorptive finish.

The bi-radiant oven that was constructed was tested under a variety of cooking conditions (including the DOE test procedure) and also modeled (using computer thermal analysis programs) to determine its performance. It demonstrated a greater than 50% increase in efficiency over that of a conventional oven. In addition, the separate upper and lower heating elements required by the oven provided more flexibility in baking and roasting.

It was pointed out in the analysis that several important practical concerns have to be addressed by manufacturers in order to realize the demonstrated energy savings. The first concerns the oven lining material, since the low-emissivity cavity surface (less than 0.1) must be maintainable. Second, microprocessor controls must be used. And third, as mentioned earlier, the baking and roasting utensils must have a highly absorptive exterior. It was assumed that manufacturers would be able to overcome these problems and produce an operational oven incorporating a bi-radiant design. Thus, this design option was analyzed for electric ovens. We assumed a 50% efficiency increase.

Halogen Lamp Oven (Electric Ovens Only)

Halogen elements, similar to what are used in electric cooktops, can also be used in electric ovens. This oven type was first introduced in Europe, but according to U.S. manufacturers, its acceptance has been slow in the United States. Manufacturers state that the cooking performance of the halogen lamp oven is relatively poor compared to that of a conventional oven, though it might be advantageous for certain broiling applications.

No data were found or presented to demonstrate how efficiently the halogen lamp oven performs relative to conventional ovens. Because of this, it was not analyzed as a design option for electric ovens.

1.4.2 Energy Use Data for Ovens

As discussed in the Energy Use Data section for cooktops, an energy-labeling program has never been instituted for cooking appliances. Thus, no directories exist that provide the efficiency of oven models produced by manufacturers. Without a statistical data base to select appropriate baseline efficiencies for ovens, data from several different sources were used to determine baseline cooking efficiencies for the four oven product classes.

For standard electric ovens the following sources were used: manufacturers' data provided by AHAM, a costing analysis of design options for residential appliances prepared by ADM Associates for LBNL (55), an energy efficient-electrical product knowledge base prepared by ORTECH International for the Canadian Electrical Association (56), and a 1980 DOE Engineering Analysis for residential appliances (57). Additional baseline efficiency data was submitted by ADL (58) as part of the comment response to the NOPR. The data provided by these sources resulted in a baseline cooking efficiency of 12.10%. The clock on the baseline oven was determined to have a power consumption of 3.9 watts. The volume of the oven cavity was assumed to be 3.9 ft^3 with 2-inches of fiberglass insulation (density of 1.09 lb/ft^3) in the cabinet walls and door.

For self-cleaning electric ovens, the volume of the oven cavity was also assumed to be 3.9 ft^3. The cabinet walls and doors were assumed to contain 2-inches of 1.90 lb/ft^3 fiberglass insulation. The same sources that were used to determine the baseline cooking efficiency of standard electric ovens were also used to determine the cooking efficiency of self-cleaning ovens. In addition to these sources, manufacturers' data provided by the Canadian Standards Association (CSA) were also used (59). Additional baseline efficiency data was submitted by AHAM (60) as part of the comment response to the NOPR. The data provided by these sources resulted in a baseline cooking efficiency of 13.79% for self-cleaning electric ovens. The self-cleaning energy consumption (E_S), as measured according to the DOE test procedure, and the power consumption of the clock (E_{CL}) were determined to be 5286 watt-hours/cycle and 3.8 watts, respectively. The same data that were averaged to determine the baseline cooking efficiency were also averaged to establish both the self-cleaning energy consumption and the power consumption of the clock.

The same sources that were used to determine the baseline cooking efficiency of standard electric ovens (with the exception of the data provided by ORTECH) were also used to establish the cooking efficiency of standard gas ovens. The averaged result provided a baseline cooking efficiency of 5.92%. The baseline oven was assumed to have no electrical power cord and a standing pilot ignition system. The pilot light consumption was assumed to be 175 Btu/hr. The volume of the oven cavity was assumed to be 3.9 ft^3 with 2-inches of fiberglass insulation (density of 1.09 lb/ft^3) in the cabinet walls and door.

The only sources of information that were used to establish the baseline cooking efficiency of self-cleaning gas ovens were manufacturers' data provided by AHAM and the costing analysis prepared by ADM Associates (61). Averaging the data provided by these sources resulted in a cooking efficiency of 7.13%. The baseline oven was assumed to have an electrical power cord and an electric "glo" type ignition system. The electric ignition system was determined to have a power consumption of 384 watts. This translates into an electrical energy consumption of 176 watt-hours during both the cooking and self-cleaning cycles of the DOE test. The self-cleaning energy consumption (E_S), as measured according to the DOE test procedure, and the power demand of the clock (E_{CL}) were determined to be 43,158 Btu/cycle and 3.6 watts, respectively. The same data that were averaged to determine the baseline cooking efficiency were also used to establish the energy consumption of the electric ignition system, the energy consumed during the self-cleaning cycle, and the power consumption of the clock.

An energy factor is used to rate the efficiency performance of ovens. The cooking efficiency is only one of several quantities needed to determine the energy factor of an electric or gas oven. Before presenting the baseline energy factors for the four product classes of ovens described above, the equations which are used to calculate the energy factors are first presented. For electric ovens (both standard and self-cleaning), the energy factor, as defined by the DOE test procedure, is represented by Eq. 1.6. The energy factor is a function of the annual useful cooking energy output and the total annual energy consumption.

$$R_o = O_o / E_{AO} \tag{1.6}$$

where:

R_O = energy factor,
O_O = annual useful cooking energy output (kWh), and
E_{AO} = total annual energy consumption (kWh).

The total annual energy consumption, in turn, is represented by Eq. 1.7.

$$E_{AO} = E_{CO} + E_{SC} + E_{CL} \tag{1.7}$$

where: E_{CO} = annual cooking energy consumption (kWh),
E_{SC} = annual self-cleaning energy consumption (kWh), and
E_{CL} = annual clock energy consumption (kWh).

The annual cooking energy consumption for electric ovens is represented by Eq. 1.8.

$$E_{CO} = O_O / Eff \tag{1.8}$$

where: O_O = annual useful cooking energy output (kWh), and
Eff = cooking efficiency.

And finally, the annual self-cleaning and clock energy consumptions are represented by Eqs. 1.9 and 1.10, respectively.

$$E_{SC} = E_S \bullet S_e \bullet C \qquad \textbf{(1.9)}$$

where:

E_S = energy consumption measured during the self-cleaning operation (watt-hours),

S_e = average number of times a self-cleaning operation of an electric oven is used per year[1], and

C = 0.001 kW/W, conversion factor of watts to kilowatts.

$$E_{CL} = P_{CL} \bullet H_K \qquad \textbf{(1.10)}$$

where:

P_{CL} = power rating of clock (watts), and

H_K = 8,760 hours in a year.

Thus, as long as the cooking efficiency and the power rating of the clock are known, the energy factor of a standard electric oven can be determined. In addition to the cooking efficiency and the clock's power rating, the energy consumption during the self-cleaning operation must also be known to determine the energy factor of a self-cleaning electric oven.

Because gas ovens equipped with an electrical power cord also consume electrical energy in addition to gas energy, the DOE test procedure equations for determining the energy factor are more involved than those for electric ovens. The energy factor for gas ovens, as defined by the DOE test procedure, is represented by Eq. 1.11.

$$R_O = O_O \,/\, [E_{AOG} + (E_{AOE} \bullet H_e)] \qquad \textbf{(1.11)}$$

where:

R_O = energy factor,

O_O = annual useful cooking energy output (Btu),

E_{AOG} = total annual gas energy consumption (Btu),

E_{AOE} = total annual electrical energy consumption (kWh), and

H_e = 3,412 Btu/kWh, conversion factor.

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[1] According to the existing and proposed DOE test procedures, the average number of self-clean cycles per year for electric self-cleaning ovens is 11. More recent data from the Gas Research Institute's 1994 report entitled *Topical Report: Technical Input to NAECA Rulemaking for Gas-Fired Ranges* (GRI-94/0195) indicates that the maximum number of self-clean cycles for self-cleaning ovens is 4.

The total annual gas and electrical energy consumptions are, in turn, represented by Eqs. 1.12 and 1.13.

$$E_{AOG} = E_{CO} + E_{PO} + E_{SC} \tag{1.12}$$

where:

E_{CO} = annual primary cooking-energy consumption (Btu),
E_{PO} = annual pilot energy consumption (Btu), and
E_{SC} = annual primary self-cleaning energy consumption (Btu).

$$E_{AOE} = E_{SO} + E_{SS} + E_{CL} \tag{1.13}$$

where:

E_{SO} = annual secondary cooking-energy consumption (kWh),
E_{SS} = annual secondary self-cleaning energy consumption (kWh), and
E_{CL} = annual clock energy consumption.

The components of the annual primary (i.e., natural gas) energy consumption (E_{CO}, E_{PO}, E_{SC}) are represented by Eqs. 1.14, 1.15, and .1.16.

$$E_{CO} = (O_O / Eff) - [(E_{IO} \bullet H_e \bullet O_O) / (W_1 \bullet C_P \bullet T)] \tag{1.14}$$

where:

O_O = annual useful cooking-energy output (Btu),
Eff = cooking efficiency,
E_{IO} = electrical test energy consumption (kWh),
W_1 = 8.5 lbs., measured weight of test block,
C_P = 0.23 Btu/lb.-°F, specific heat of test block, and
T = 234 °F, temperature rise of test block.

$$E_{PO} = P \bullet (A - B) \tag{1.15}$$

where:

P = pilot light consumption (Btu),
A = 8760, number of hours in a year, and
B = 300, number of hours any continuously burning pilot lights contribute to the heating of an oven for cooking food.

$$E_{SC} = E_S \bullet S_g \tag{1.16}$$

where:

E_s = energy consumption measured during the self-cleaning operation (Btu),
S_g = average number of times a self-cleaning operation of a gas oven is used per year[2].

Two of the components of the annual electrical energy consumption (E_{AOE}) are represented by previous equations. The annual secondary cooking-energy consumption (E_{SO}) is represented by the second term in Eq. 1.13. The annual clock energy consumption (E_{CL}) is represented by Eq. 1.10. The annual secondary self-cleaning energy consumption (E_{SS}), is determined by using Eq. 1.17.

$$E_{SS} = E_{IS} \bullet S_g \bullet C \tag{1.17}$$

where:

E_{IS} = electrical energy consumed during the self-cleaning operation (watt-hours),
S_g = average number of times a self-cleaning operation of a gas oven is used per year, and
C = 0.001 kW/W, conversion factor of watts to kilowatts.

Thus, in addition to knowing the cooking efficiency and the power rating of the clock, the pilot energy consumption and any miscellaneous electrical energy consumption must also be known to determine the energy factor of a standard gas oven. To determine the energy factor for self-cleaning gas ovens, both the primary and secondary self-cleaning energy consumptions must be known in addition to the same quantities that must be known for standard gas ovens.

As evidenced by Eqs. 1.6 and 1.8 for electric ovens, and Eqs. 1.11 and 1.14 for gas ovens, both the energy factor and cooking efficiency are dependant upon what value is used for the annual useful cooking energy output (O_o). The DOE test procedure establishes an annual useful cooking energy output value of 47.09 kWh/yr and 160,700 Btu/yr for electric and gas ovens, respectively. But since these values were established by the DOE test procedure in the late 1970s, manufacturers have contended that new values for the annual useful cooking energy output should be determined due to the drastic changes that have occurred in cooking habits. This issue was also of concern in the analysis of cooktops, and revised values for the annual useful cooking energy output were derived from various gas and electric utility reports from the years 1977 through 1988. The analysis for ovens used the same utility reports to determine updated values for the annual useful cooking energy output. These utility reports used either conditional demand analyses or metered data to establish the annual energy use of cooking appliances. Based on these utility reports, the revised annual useful

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[2] According to the existing and proposed DOE test procedures, the average number of self-clean cycles per year for gas self-cleaning ovens is 7. More recent data from the Gas Research Institute's 1994 report entitled *Topical Report: Technical Input to NAECA Rulemaking for Gas-Fired Ranges* (GRI-94/0195) indicates that the maximum number of self-clean cycles for self-cleaning ovens is 4.

cooking energy output values were determined to be 35.5 kWh/yr and 124,200 Btu/yr for electric and gas ovens, respectively. The revised annual useful cooking energy output values were part of DOE's proposed revisions in March, 1995 to the test procedure for kitchen ranges and ovens (62). Section A.1 in Volume 2, Appendix A of this TSD provides a detailed description of the analysis that was developed to determine the revised annual useful cooking energy output values for the DOE proposed test procedure.

Based upon comments to both DOE's proposed test procedure and their proposed minimum efficiency standards for kitchen ranges and ovens, further analysis was conducted to update the values that were proposed by DOE for the annual useful cooking energy output. More recent energy usage data derived solely from metered sources (sources preceding the year 1988 were not considered) were used to establish new values for the annual useful cooking energy output. The new values were even lower than those issued by DOE in its proposed test procedure and were determined to be 29.3 kWh/yr and 88,800 Btu/yr for electric and gas ovens, respectively. Section A.2 in Volume 2, Appendix A of this TSD provides a detailed description of the analysis that was developed to determine the annual useful cooking energy output values based on recent annual energy usage data.

Table 1.10 presents the baseline energy factors and cooking efficiencies for the four oven product classes. Energy factors are presented based on using annual useful cooking energy output values determined from the existing DOE test procedure, the proposed DOE test procedure, and the most recent energy usage data.

Table 1.10 Baseline Oven Energy Factors and Cooking Efficiencies

		Energy Factor		Cooking
Product Class	**Existing DOE**	**Proposed DOE**	**Recent**	**Efficiency**
Electric Standard	11.2%	10.9%	10.7%	12.15%
Electric Self-Clean	10.9%	10.2%	9.6%	13.79%
Gas Standard	3.8%	3.5%	3.0%	5.92%
Gas Self-Clean	6.0%	5.8%	5.4%	7.13%

In the previous section on design options, information was presented on how each design option impacted the cooking efficiency. Increases in cooking efficiency as a result of incorporating prospective design options were either expressed as a percentage increase or an absolute percentage point increase. For design options that increase the cooking efficiency on a percentage basis, rather than on an absolute percentage point basis, the percentage increase is applied to the baseline model's cooking efficiency. The resulting percentage point increase is then added to the preceding design option's cooking efficiency to obtain the appropriate value. The design option's impact on other areas of energy consumption, besides the cooking efficiency, were also noted (e.g., a gas oven electric ignition system eliminating the pilot energy consumption but adding electrical energy use).

The results of the energy efficiency analysis for standard electric ovens are presented in Table 1.11. For each design option, the efficiency (*Eff*), the clock energy consumption (E_{CL}), the annual cooking-energy consumption (E_{CO}), the total annual energy consumption (E_{AO}), and the energy factor (EF) are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of standard electric ovens, two sets of values are presented for the total annual energy consumption and the energy factor. One set of values is based on using the annual useful cooking energy output from the proposed DOE test procedure (35.5 kWh/yr) and the other set is based on using the value from the more recent energy usage data (29.3 kWh/yr). Even though the annual cooking energy consumption is a function of the annual useful cooking energy output, only the value based on the proposed DOE test procedure is provided in Table 1.11. The annual cooking energy consumption based on more recent energy usage data is determined simply by multiplying the proposed test procedure's value by the ratio of the "recent"-to-"proposed" annual useful cooking energy output values (29.3 to 35.5 kWh/yr). The clock energy consumption is not a function of the annual useful cooking-energy output and is the same regardless of what value is chosen for the annual useful cooking energy output. Refer to Eqs. 1.6 through 1.10 to determine how the above quantities were calculated. Notes are provided with Table 1.11 indicating how each design option impacts the cooking efficiency. Also included in Table 1.11 are the total manufacturing costs for each design option. These costs will be explained in the next section (Cost and Efficiency Data for Ovens).

The results of the energy efficiency analysis for self-cleaning electric ovens are presented in Table 1.12. For each design option, the efficiency (Eff), the clock energy consumption (E_{CL}), the annual cooking-energy consumption (E_{CO}), the annual self-cleaning energy consumption (E_{SC}), the total annual energy consumption (E_{AO}), and the energy factor (EF) are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of self-cleaning electric ovens, two sets of values are presented for the total annual energy consumption and the energy factor. One set of values is based on using the annual useful cooking energy output from the proposed DOE test procedure (35.5 kWh/yr) and the other set is based on using the value from the more recent energy usage data (29.3 kWh/yr). Even though the annual cooking energy consumption is a function of the annual useful cooking energy output, only the value based on the proposed DOE test procedure is provided in Table 1.12. The annual cooking energy consumption based on more recent energy usage data is determined simply by multiplying the proposed test procedure's value by the ratio of the "recent"-to-"proposed" annual useful cooking energy output values (29.3 to 35.5 kWh/yr). The clock energy consumption and the annual self-cleaning energy consumption are not a function of the annual useful cooking energy output and are the same regardless of what value is chosen for the annual useful cooking energy output. Refer back to Eqs. 1.6 through 1.10 to determine how the above quantities were calculated. Notes are provided with Table 1.12 indicating how each design option impacts the cooking efficiency. Also included in Table 1.12 are the total manufacturing costs for each design option. These costs will be explained in the next section (Cost and Efficiency Data for Ovens).

Table 1.11 Cost-Efficiency Table for Standard Electric Ovens

Energy Efficiency Level	Design No.	Design Option	Mfg. Cost 1990$	Eff %	E_{CL} kWh	Proposed[9] E_{CO}[11] kWh	Proposed[9] E_{AO} kWh	Proposed[9] EF %	Recent[10] E_{AO} kWh	Recent[10] EF %
	0	Baseline[1]	146.17	12.2	33.8	292.2	326.0	10.9	274.9	10.7
1	1	0 + Reduced Vent Rate[2]	147.80	12.8	33.8	278.0	311.8	11.4	263.2	11.1
2	2	1 + Improved Insulation[3]	151.01	13.4	33.8	264.1	297.9	11.9	251.8	11.6
3	3	2 + Improved Door Seals[4]	154.70	13.7	33.8	259.5	293.3	12.1	248.0	11.8
4	4	3 + Bi-Radiant Oven[5]	217.20	21.6	33.8	164.5	198.3	17.9	169.6	17.3
	5	4 + Oven Separator[6]	228.95	22.4	33.8	158.5	192.3	18.5	164.6	17.8
	6	5 + Forced Convection[7]	268.56	22.7	33.8	156.2	190.0	18.7	162.7	18.0
5	7	6 + Red. Conduction Losses[8]	272.11	22.8	33.8	155.9	189.6	18.7	162.4	18.0

Notes:
(1) Baseline: Cooking Efficiency = 12.15%, Clock Power = 3.9 watts, 2" of 1.09 lb/cu ft insulation
(2) Reduced Vent Rates: Cooking Efficiency Increase = 0.62 (absolute percentage points)
(3) Improved Insulation: Cooking Efficiency Increase = 0.52% (relative percent)
(4) Improved Door Seals: Cooking Efficiency Increase = 0.24 (absolute percentage points)
(5) Bi-Radiant Oven: Cooking Efficiency Increase = 50.0% (relative percent)
(6) Oven Separator: Cooking Efficiency Increase = 0.82 (absolute percentage points)
(7) Forced Convection: Cooking Efficiency Increase = 0.33 (absolute percentage points)
(8) Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 (absolute percentage points)
(9) "Proposed" E_{CO}, E_{AO} and EF based on proposed DOE test procedure annual useful cooking energy output of 35.5 kWh/yr
(10) "Recent" E_{AO} and EF based on recent energy usage data yielding an annual useful cooking energy output of 29.3 kWh/yr
(11) "Recent" E_{CO} is determined by the following calculation: $E_{CO\ RECENT} = E_{CO\ PROPOSED} \bullet (29.3 / 35.5)$

Table 1.12 Cost-Efficiency Table for Self-Cleaning Electric Ovens

Energy Efficiency Level	Design No.	Design Options	Mfg. Cost 1990$	Eff %	E_{CL} kWh	E_{SC} kWh	Proposed[6] E_{CO}[8] kWh	Proposed[6] E_{AO} kWh	Proposed[6] EF %	Recent[7] E_{AO} kWh	Recent[7] EF %
1,2,3	0	Baseline[1]	185.15	13.8	33.1	58.2	257.4	348.7	10.2	303.7	9.6
4	1	0 + Bi-Radiant Oven[2]	247.65	22.8	33.1	58.2	156.0	247.3	14.4	220.0	13.3
	2	1 + Oven Separator[3]	259.85	23.6	33.1	58.2	150.6	241.8	14.7	215.5	13.6
	3	2 + Red. Conduction Losses[4]	264.22	23.6	33.1	58.2	150.3	241.5	14.7	215.3	13.6
5	4	3 + Forced Convection[5]	303.83	24.0	33.1	58.3	148.2	239.6	14.8	213.7	13.7

Notes:
(1) Baseline: Cooking Efficiency = 13.79%, Clock Power = 3.8 watts, 2" of 1.90 lb/cu ft insulation, Self-Cleaning Energy Consumption = 5286 watt-hours
(2) Bi-Radiant Oven: Cooking Efficiency Increase = 65.0% (relative percent)
(3) Oven Separator: Cooking Efficiency Increase = 0.82 (absolute percentage points)
(4) Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 (absolute percentage points)
(5) Forced Convection: Cooking Efficiency Increase = 0.33 (absolute percentage points)
(6) "Proposed" E_{CO}, E_{AO} and EF based on proposed DOE test procedure annual useful cooking energy output of 35.5 kWh/yr
(7) "Recent" E_{AO} and EF based on recent energy usage data yielding an annual useful cooking energy output of 29.3 kWh/yr
(8) "Recent" E_{CO} is determined by the following calculation: $E_{CO\ RECENT} = E_{CO\ PROPOSED} \bullet (29.3 / 35.5)$

The results of the energy efficiency analysis for standard gas ovens are presented in Table 1.13. For each design option, the efficiency (*Eff*), the annual pilot energy consumption (E_{PO}), the annual cooking energy consumption (E_{CO}), the annual secondary cooking energy consumption (E_{SO}), the total annual primary energy consumption (E_{AOG}), the total annual secondary energy consumption (E_{AOE}), and the energy factor (*EF*) are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of standard gas ovens, two sets of values are presented for the total annual primary and secondary energy consumptions and the energy factor. One set of values is based on using the annual useful cooking energy output from the proposed DOE test procedure (124,200 Btu/yr) and the other set is based on using the value from the more recent energy usage data (88,800 Btu/yr). Even though both the annual cooking and annual secondary cooking energy consumptions are also a function of the annual useful cooking energy output, only the values based on the proposed DOE test procedure are provided in Table 1.13. The cooking energy consumptions based on more recent energy usage data are determined simply by multiplying the proposed test procedure's values by the ratio of the "recent"-to-"proposed" annual useful cooking energy output values (88,800 to 124,200 Btu/yr). The annual pilot energy consumption is not a function of the annual useful cooking energy output and is the same regardless of what value is chosen for it. Refer to Eqs. 1.11 through 1.17 to determine how the above quantities were calculated. Notes are provided with Table 1.13 indicating how each design option impacts the cooking efficiency. Also included in Table 1.13 are the total manufacturing costs for each design option. These costs will be explained in the next section (Cost and Efficiency Data for Ovens).

The results of the energy efficiency analysis for self-cleaning gas ovens are presented in Table 1.14. For each design option, the efficiency (*Eff*), the annual clock energy consumption (E_{CL}), the annual cooking energy consumption (E_{CO}), the annual secondary cooking energy consumption (E_{SO}), the annual primary self-cleaning energy consumption (E_{SC}), the annual secondary self-cleaning energy consumption (E_{SS}), the total annual primary energy consumption (E_{AOG}), the total annual secondary energy consumption (E_{AOE}), and the energy factor (*EF*) are presented. In order to demonstrate how the annual useful cooking energy output impacts the calculated energy use of self-cleaning gas ovens, two sets of values are presented for the total annual primary and secondary energy consumptions and the energy factor. One set of values is based on using the annual useful cooking energy output from the proposed DOE test procedure (124,200 Btu/yr) and the other set is based on using the value from the more recent energy usage data (88,800 Btu/yr). Even though both the annual cooking and annual secondary energy consumptions are also a function of the annual useful cooking energy output, only the values based on the proposed DOE test procedure are provided in Table 1.14. The cooking energy consumptions based on more recent energy usage data are determined simply by multiplying the proposed test procedure's values by the ratio of the "recent"-to-"proposed" annual useful cooking energy output values (88,800 to 124,200 Btu/yr). Both the primary and secondary self-cleaning annual energy consumptions, as well as the clock energy consumption, are not a function of the annual useful cooking-energy output and are the same regardless of what value is chosen for the annual useful cooking energy output. Refer to Eqs. 1.11 through 1.17 to determine how the above quantities were calculated. Notes are provided with Table 1.14 indicating how each design option impacts the cooking efficiency. Also included in Table 1.14 are the total manufacturing costs for each design option. These costs will be explained in the next section (Cost and Efficiency Data for Ovens).

Table 1.13 Cost-Efficiency Table for Standard Gas Ovens

Energy Effc'y Level	Des. No.	Design Option	Mfg. Cost 1990$	Eff. %	E_{PO} kBtu	Proposed[10] E_{CO}[12] kBtu	E_{SO}[12] kWh	E_{AOG} kBtu	E_{AOE} kWh	EF %	Recent[11] E_{AOG} kBtu	E_{AOE} kWh	EF %
1,2	0	Baseline[1]	154.80	5.9	1481	2100	0.0	3580	0.0	3.5	2982	0.0	3.0
3	1	0 + Electric Glo-bar Ignition[2]	166.86	5.8	0	1969	47.8	1969	47.8	5.8	1408	34.2	5.8
	2	1 + Improved Insulation[3]	170.44	6.1	0	1867	47.8	1867	47.8	6.1	1335	34.2	6.1
4	3	2 + Improved Door Seals[4]	171.52	6.2	0	1848	47.8	1848	47.8	6.2	1321	34.2	6.2
	4	3 + Forced Convection[5]	193.66	6.5	0	1735	51.9	1735	51.9	6.5	1240	37.1	6.5
	5	4 + Reduced Vent Rate[6]	195.28	6.5	0	1726	51.9	1726	51.9	6.5	1234	37.1	6.5
5	6	5 + Oven Separator[7]	223.54	6.5	0	1724	51.9	1724	51.9	6.5	1233	37.1	6.5
	7	6 + Red. Conduction Losses[8]	227.17	6.6	0	1715	51.9	1715	51.9	6.6	1227	37.1	6.6
	8	0 + Electronic Spark Ignition[9]	169.80	5.8	0	2132	0.0	2132	0.0	5.8	1524	0.0	5.8

Notes:

(1) Baseline: Cooking Efficiency = 5.92%, 2" of 1.09 lb/cu ft insulation, Standing Pilot Ignition = 175 Btu/hour

(2) Electric Ignition: Cooking Efficiency Decrease = 0.152 (absolute percentage points), Added Electricity Consumption = 176 watt-hours

(3) Improved Insulation: Cooking Efficiency Increase = 4.9% (relative percent)

(4) Improved Door Seals: Cooking Efficiency Increase = 1.0 % (relative percent)

(5) Forced Convection: Cooking Efficiency Increase = 4.8% (relative percent), Added Electricity Consumption = 15 watt-hours

(6) Reduced Vent Rates: Cooking Efficiency Increase = 0.5% (relative percent)

(7) Oven Separator: Cooking Efficiency Increase = 0.1% (relative percent)

(8) Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 (absolute percentage points)

(9) Electronic Ignition: Cooking Efficiency Decrease = 0.09 (absolute percentage points), Added Electricity Consumption = 0.0 watt-hours

(10) "Proposed" E_{CO}, E_{SO}, E_{AOE}, E_{AOG} and EF based on proposed DOE test procedure annual useful cooking energy output of 124.2 kBtu/yr

(11) "Recent" E_{AOG} and EF based on recent energy usage data yielding an annual useful cooking energy output of 88.8 kBtu/yr

(12) "Recent" E_{CO} and E_{SO} are determined by the following calculation: $E_{RECENT} = E_{PROPOSED} \bullet (88,800 / 124,200)$

Table 1.14 Cost-Efficiency Table for Self-Cleaning Gas Ovens

Energy Effc'y Level	Des. No.	Design Options	Mfg. Costs 1990$	Eff. %	E_{SC} kBtu	E_{SS} kWh	E_{CL} kWh	Proposed[6] E_{CO}[8] kBtu	E_{SO}[8] kWh	E_{AOG} kBtu	E_{AOE} kWh	EF %	Recent[7] E_{AOG} kBtu	E_{AOE} kWh	EF %
1,2,3,4	0	Baseline[1]	220.26	7.1	302.1	1.2	31.3	1580	47.8	1882	80.3	5.8	1432	66.7	5.4
	1	0 + Forced Convect.[2]	231.27	8.8	302.1	1.3	31.3	1242	51.9	1544	84.5	6.8	1190	69.7	6.2
	2	1 + Red. Cond. Loss.[3]	235.64	8.8	302.1	1.3	31.3	1234	51.9	1536	84.5	6.8	1184	69.7	6.2
	3	2 + Impr. Door Seals[4]	236.86	8.9	302.1	1.3	31.3	1223	51.9	1525	84.5	6.9	1176	69.7	6.3
5	4	3 + Oven Separator[5]	282.83	9.4	302.1	1.3	31.3	1144	51.9	1446	84.5	7.2	1120	69.7	6.5

Notes:

(1) Baseline: Cooking Efficiency = 7.13%, Clock Power = 3.6 watts, 2" of 1.90 lb/cu ft insulation, Electric Ignition = 176 watt-hours, Self-Cleaning Energy Consumption = 43,158 Btu

(2) Forced Convection: Cooking Efficiency Increase = 23% (relative percent), Added Electricity Consumption (during cooking and cleaning cycles) = 15 Watt-hours

(3) Reduced Conduction Losses: Cooking Efficiency Increase = 0.05 (absolute percentage points)

(4) Improved Door Seals: Cooking Efficiency Increase = 1.0% (relative percent)

(5) Oven Separator: Cooking Efficiency Increase = 0.53 (absolute percentage points)

(6) "Proposed" E_{CO}, E_{SO}, E_{AOE}, E_{AOG} and EF based on proposed DOE test procedure annual useful cooking energy output of 124.2 kBtu/yr

(7) "Recent" E_{AOG} and EF based on recent energy usage data yielding an annual useful cooking energy output of 88.8 kBtu/yr

(8) "Recent" E_{CO} and E_{SO} are determined by the following calculation: $E_{RECENT} = E_{PROPOSED} \bullet (88,800 / 124,200)$

The four oven product classes all have different maximum technologically feasible design options. The "max tech" design option for all the ovens can be found by reviewing Tables 1.11 through Table 1.14. The "max tech" oven design includes all those design options up to and including the energy efficiency level 5 design option. For standard electric ovens this includes: reduced vent rate, improved insulation, improved door seals, bi-radiant oven, oven separator, forced convection, and reduced conduction losses. For self-cleaning electric ovens this includes: bi-radiant oven, oven separator, reduced conduction losses, and forced convection. For standard gas ovens this includes: electric ignition, improved insulation, improved door seals, forced convection, reduced vent rate, and oven separator. For self-cleaning gas ovens this includes: forced convection, reduced conduction losses, improved door seals, and oven separator.

As with cooktops, the minimum technologically feasible energy use for the four oven product classes is based upon the value chosen for the annual useful cooking energy output. When the "most recent" annual useful cooking energy output value is used, the minimum energy uses are: 162.4 kWh/year for standard electric ovens, 213.7 kWh/year for self-cleaning electric ovens, 1227 Btu/year and 37.1 kWh/year for standard gas ovens, and 1120 Btu/year and 69.7 kWh/year for self-cleaning gas ovens.

Energy Use Versus Volume

The variation between the energy factor and oven volume results from the fact that larger ovens have higher thermal mass and larger vent rates than smaller ovens. Since the test procedure for establishing an energy rating is a transient test with a fixed test load, the increased energy consumption due to increased mass with larger units yields a lower energy factor. The 1980 DOE Engineering Analysis for residential appliances (63) established a relationship between oven volume and energy factor from data compiled by the National Bureau of Standards (NBS now called NIST). Using these data, linear equations were derived for electric and gas ovens. No distinction was found to exist between standard and self-cleaning ovens. The values for these slopes (where energy factor is a function of oven volume) were determined to be -0.0157 for electric ovens and -0.0073 for gas ovens where the energy factor is expressed as a decimal and the volume in cubic feet. Intercepts for a particular baseline model or oven design were chosen so that the equations pass through the desired energy factor corresponding to a particular volume.

Since data were not available to determine the relationships between energy factor and volume for ovens currently being produced, the above slopes derived from the NBS data are used to define the relationship for oven models presently being made. Table 1.15 presents the intercepts for each of the energy efficiency levels that have been chosen for the four oven product classes.

Table 1.15 Intercepts for Energy Factor vs. Volume Relationships

Energy Efficiency	Electric		Gas	
Level	Standard	Self-Clean	Standard	Self-Clean
1	0.1752	0.1632	0.0865	0.0865
2	0.1802	0.1632	0.0865	0.0865
3	0.1822	0.1632	0.0895	0.0865
4	0.2402	0.2042	0.0935	0.0865
5	0.2482	0.2092	0.0935	0.1005

Note: Intercepts are used in equation of the form EF = (slope x volume) + intercept

1.4.3 Cost and Efficiency Data for Ovens

In this section, cost and efficiency data are discussed for the four oven product classes. The cost data consists of manufacturer, maintenance, and installation costs. The manufacturer cost is the cost to the manufacturer of producing products with the design options shown, and does not include markups to wholesalers or retailers.

The maintenance cost is annualized over the lifetime of the product and is incorporated as an operating cost to the consumer of maintaining the operation of the oven. The only design option that incurs a maintenance cost is the electronic ignition system for standard gas ovens. All other design options, for both electric and gas ovens, were assumed not to increase the cost of maintaining the operation of the oven. The maintenance cost consists of replacement parts and labor. In order to estimate the maintenance cost of electronic ignition devices, a retirement function was constructed for two of the device's components: the control module and the sensor. All other electronic ignition components were assumed to last the lifetime of the appliance. The lifetime of both gas and electric ovens was assumed to be 19 years (64). The retirement function is a curve of component lifetime versus the year of component failure. The function was constructed from information provided by electronic ignition manufacturers. For more details regarding the development of this maintenance cost, please refer to Appendix D in Volume 1 of this TSD.

The installation cost is the added first cost of having a contractor or appliance service person install the oven in a home. It does not include the retail cost of the oven. Included in the installation cost is the installation of an electrical outlet for those homes which may need one for a pilotless ignition. See Section 1.3.3 for a discussion of the installation cost for gas cooking equipment.

The cost and efficiency data were combined and presented in Tables 1.11 to 1.14, in the previous section on Energy Use Data for Ovens. Appendix A.3 contains disaggregated manufacturers' costs for the four oven product classes. Total manufacturer costs are divided into material, labor, tooling, shipping, and indirect costs. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. Several sources were used in establishing the costs. AHAM supplied manufacturers' cost estimates for reducing the vent rate and improving the insulation in standard gas and electric ovens. In addition, AHAM supplied, for all four oven product classes, manufacturers' cost data for the following design options: the addition of reflective surfaces to the oven cavity, added insulation to the oven walls and door, reduced thermal mass within the oven cavity, reduced conduction losses by installing an upgraded oven door, and the addition of an oven separator. Independent of any trade organization, a few oven manufacturers provided manufacturers' cost data for the forced convection design option. Estimates of manufacturers' costs were obtained from suppliers for only one design option: electric ignition devices for gas ovens. A 1980 DOE Engineering Analysis for residential appliances (65) was used to help estimate the cost of adding insulation and improving the insulation in gas and electric ovens. A report by ADM Associates for LBNL (66) was used to help estimate the cost of reducing the vent rate and improving the insulation in standard gas and electric ovens. An appliance knowledge base prepared by Rocky Mountain Institute (67) was used to estimate the cost of producing a bi-radiant electric oven. An energy-efficient electrical product knowledge base prepared by ORTECH International (68) for the Canadian Electrical Association was used to estimate the cost of improving door seals in gas ovens and standard electric ovens.

1.4.4 Maximum Technologically Feasible Design

The maximum technologically feasible designs for the four oven product classes were previously discussed in the Energy Use Data for Ovens section. The efficiency of the "max tech" design was derived from data given by manufacturers plus a variety of other sources. All of the efficiency values (and manufacturing costs as well) in Tables 1.11 through 1.14 have some uncertainty associated with them.

A 95% confidence interval for the "max tech" design's energy factor has been determined for each of the four oven product classes. The range of this interval is different for each product class.

The low and high ends of the 95% confidence interval for standard electric ovens are approximately the same. The low end of the interval is approximately 7.0% lower than the "max tech" design's energy factor, while the high end of the interval is approximately 6.2% higher the "max tech" design's energy factor.

The low and high ends of the 95% confidence interval for self-cleaning electric ovens are also approximately the same. The low end of the interval is approximately 5.3% lower than the "max tech" design's energy factor, while the high end of the interval is approximately 5.0% higher than the "max tech" design's energy factor.

The low and high ends of the 95% confidence interval for standard gas ovens are also approximately the same. The low end of the interval is 14.1% lower than the "max tech" design's energy factor while the high end of the interval is 16.6% higher than the "max tech" design's energy factor.

The low and high ends of the 95% confidence interval for self-cleaning gas ovens varies only slightly. The low end of the interval is approximately 10.6% lower than the "max tech" design's energy factor while the high end of the interval is approximately 11.0% higher than the "max tech" design's energy factor.

Volume 1 (General Methodology) of this TSD provides a general discussion of how the 95% confidence interval is established for "max tech" designs.

1.5 MICROWAVE OVENS

1.5.1 Design Options for Microwave Ovens

The design options are changes that can be incorporated into the design of a microwave oven to improve its energy efficiency. The designs that were considered are shown in Table 1.16. A microwave oven operates by generating microwave energy at a frequency that is absorbed by the water molecules in food.

Table 1.16 Design Options for Microwave Ovens

1. Add Insulation
2. Use Reflective Surfaces
3. Use More Efficient Fan
4. Improve Efficiency of Magnetron
5. Improve Efficiency of the Power Supply
6. Eliminate of Improve Ceramic Stirrer Cover
7. Modify Wave Guide

Add Insulation

Adding insulation to the outside of the reflective interior surface of the oven would diminish heat flow through the walls of the oven. However, there is very little difference in temperature between the inside and the outside of the microwave oven; therefore, the efficiency improvement from adding insulation would probably not be measurable (69). For this reason, this design option was not analyzed.

Use Reflective Surfaces

Microwave ovens are designed so as to have surfaces that are highly reflective of microwave energy. A high-grade stainless steel cavity would be more reflective than a painted or porcelainized cavity interior. Testing by manufacturers has shown that high-grade stainless steel (or reflective material steel coating) would be more efficient than painted cold-rolled steel by approximately 0.5% (70).

Use More Efficient Fan

Microwave ovens use either one or two fans. One fan is used to remove heat generated by the magnetron from the cavity. The second fan would be used where mode stirring is accomplished by using slow-moving metal blades. This allows for better distribution of the microwave energy. Since power demand is very low (2-3 watts), there is no opportunity for energy savings in models with a second fan. The blower fan that is used to cool the magnetron and other electrical components uses about 25 watts. Increasing the efficiency of this fan can reduce microwave oven energy consumption. Additional data was submitted during the NOPR comment period which was incorporated into this analysis. According to these data, the expected energy savings will be less than originally reported and will have increased cost. These data were averaged with the original data and included in this analysis. The increase in efficiency is estimated to be 0.23%.

Improve Efficiency of the Magnetron

Magnetrons convert electric energy input into electromagnetic energy at microwave frequency. The conversion efficiency of magnetrons produced by foreign manufacturers varies from 70 to 73% (71). The mean magnetron efficiency is approximately 71%. Domestic companies do not produce magnetrons of the size that is used in microwave ovens. Additional data were submitted during the NOPR comment period which was incorporated into this analysis. The increase in efficiency of the oven due to this design option is estimated to be 0.9%.

Improve Magnetron Power Supply Efficiency

A transformer must be used to increase the input line voltage from 120V to about 4,000V. This higher voltage is needed to operate the magnetron. A controller, which may dissipate as much as 30 watts, turns the power off and on. Present magnetron power supplies have about an 85% efficiency. An improved power supply can be obtained through reduced losses in the controller and in the iron core of the transformer. An efficiency as high as 96% is theoretically possible (72), but does not seem practicable at reasonable cost. Earlier estimates of efficiency increase were 7%. However, more recent data supplies by Sharp Electronics, Inc. (73) shows this estimate is much too high. The value used for the current analysis is 2.9% increase in power supply efficiency.

Improve Ceramic Stirrer Cover

Microwave ovens with fan type mode stirrers use a cover over the fan to prevent inadvertent damage to the fan when inserting or removing food and to prevent degradation of the wave guide due to food splatter. Such models (with browning elements) sometimes use a ceramic mode stirrer cover because plastic types may not withstand the heat generated by the heating element during the browning operation (74). These stirrers absorb some microwave energy but are needed to prevent food splatter inside the wave guide. This design option was not analyzed.

Modify Wave Guide

Wave guides provide the interface between the microwave oven cavity and the magnetron. They have very high efficiencies in current models of microwave ovens. A small improvement (about 1%) is possible through the use of special coatings on the interior surface (75). New data submitted by AHAM (76) during the NOPR comment period indicates a small efficiency improvement may be available on some microwave ovens by reducing the length or improving the finish of the waveguides. However, many of the ovens produced in 1993 already have these new features. For this reason, this design option was not analyzed.

1.5.2 Energy Use Data for Microwave Ovens

Only limited data on microwave oven power requirements and power output were available. These data were obtained from manufacturers' literature and more recently from AHAM (77) which was submitted during the NOPR comment period. Based on this recent AHAM data, for cavity sizes from 0.3 to 1.6 ft^3, input electric power varies from 975 to 2026 watts. The efficiency, which is the useful power output divided by the electric power input, ranges from 51 to 63.5% with a shipment weighted-average efficiency of 55.7%. The average input power for these data is equal to 1485 watts. This input electric power was chosen for the baseline model. Power for the magnetron tube filament and fan/other (auxiliary) are assumed to be 37 and 50 watts, respectively, for the baseline microwave oven. This auxiliary power of 87 watts accounts for 5.8 % of total input power of the baseline unit. See Figure 1.2, “Microwave Oven Cavity Volume vs. Efficiency”, and accompanying table (Table 1.3) for more detailed information.

An equation for the predicted efficiency of a microwave oven can be developed in the following way. Assume that the input power, P_{in}, goes to three locations: the magnetron tube filament, the magnetron power supply, and the fan motor/turntable/light. A transformer is used to increase the input voltage from 120V to about 4,000V. There are losses at the power supply, in conversion of electrical energy to microwave energy in the magnetron, and in delivering microwave energy to the food in the oven cavity (there are also losses through absorption in the cavity and in reflection of microwave energy back to the magnetron). The following equation can be used to calculate microwave oven efficiency (78):

$$\text{Efficiency} = (1 - P_{aux}/P_{in}) * (e_{HV} * e_M * e_{cav}) \qquad \textbf{(1.18)}$$

where P_{aux} is the sum of the power inputs to the filament, fan, and other (such as light bulb); e_{HV} is the high-voltage power supply efficiency; e_M is the magnetron efficiency, and e_{cav} is the efficiency of the wave guide and cavity. If there is no auxiliary power, the oven efficiency equals the product of the three efficiencies defined above. For the baseline model, it is assumed that the efficiencies of the power supply, magnetron, and cavity are 0.877, 0.71, and 0.95 respectively. The resulting efficiency calculated with the equation above is 0.557.

There are four factors that affect overall microwave oven efficiency: the ratio of auxiliary power to input power, and the three efficiencies defined above. Each design option can be evaluated by the above equation. For example, if the high-voltage power supply efficiency is increased from 87.7 to 91.4%, the microwave oven efficiency is increased to 58.6%. Table 1.17 summarizes the efficiency, energy use, and manufacturer cost for each design option considered.

Microwave usage pattern have changed dramatically over the past 15 years. In recent years there seems to be a trend downward in usage in some regions of the country and a steady use in other regions. This seems to be the result of lifestyle changes primarily. Therefore, the annual energy use has been recomputed at 143.2 kWh/yr based on more recent metered studies and conditional demand analysis (79), (80), (81), (82), (83). Section A.2 in Volume 2, Appendix A of the TSD provides the details on how the annual energy use of 143.2 kWh/yr was determined.

1.5.3 Cost Efficiency Data for Microwave Ovens

Manufacturer cost data for the baseline unit and for all design options except for the more efficient power supply were obtained through AHAM. The efficiency- and energy-use data were obtained as described above. For the more efficient power supply, the $8.68 incremental manufacturer cost was obtained from estimates from Sharp Electronics' submitted as NOPR comments (84).

Table 1.17 Cost-Efficiency Data for a Microwave Oven

Energy Efficiency Level	Design No.	Design Options	Mfg. Cost *1990$*	Efficiency *%*	Energy Use *kWh/yr*
1,2,3,4	0	Baseline[1]	120.00	55.7	143.2
	1	0 + More Efficient Power Supply[2]	128.68	58.6	136.1
	2	1 + More Efficient Fan[3]	137.95	58.8	135.6
	3	2 + More Efficient Magnetron[4]	152.53	59.7	133.5
5	4	3 + Reflective Surfaces[5]	171.11	60.2	132.4

Notes:
(1) Baseline: Cooking Efficiency = 55.7%
(2) Efficient Power Source: Cooking Efficiency Increase = 2.9 (absolute percentage points)
(3) Efficient Fan: Cooking Efficiency Increase = 0.23 (absolute percentage points)
(4) Efficient Magnetron: Cooking Efficiency Increase = 0.90 (absolute percentage points)
(5) Reflective Surface: Cooking Efficiency Increase = 0.50 (absolute percentage points)

1.5.4 Maximum Technologically Feasible Design

The maximum technologically feasible efficiency is achieved by combining the four design options described above. The resulting microwave oven efficiency from this analysis is 60.2 %. This result (from the design option analysis) should be compared with Figure 1.2 which shows a plot of microwave oven efficiency vs. cavity volume for ovens currently marketed. Figure 1.2 shows several units with efficiencies above 60.2%, with one unit as high as 63.5. Clearly the industry already has the ability to produce ovens well above the baseline and even higher than the maximum technologically feasible design required by NAECA analysis. The incremental manufacturer cost to achieve the maximum tecnologically feasible efficiency is about $51.11. There is an uncertainty associated with all of the efficiency and manufacturer cost estimates in the table above. For the maximum technologically achievable efficiency, it is estimated that there is a 95% confidence that it lies between 59.1 and 61.3%. For incremental manufacturer costs, we estimate the 95% confidence interval ranges from 80 to 120% of the estimated incremental cost for each design option. Therefore, for the more efficient power supply option, there is a 95% confidence that the incremental cost lies between $7.00 and $10.40.

1.6 GAS RANGES

Based on comments received during the NOPR review, especially those received from GRI (85) and AHAM (86), an analysis has been completed on gas ranges which represents more closely what is typically purchased by the consumer. According to recent shipment data, gas ranges account for approximately 87% of the gas cooking products shipped and cooktops account for the remaining 13% (87). This analysis is an attempt to uncover any advantages or disadvantages by analyzing cooking products as they are more customarily sold, i.e., as a range.

The following cost-efficiency table (Table 1.18) shows existing design options for cooktops and ovens which have been combined into a range product. The range table was generated by adding the individual design options for both the cooktop and oven. The order of the range design options was chosen by considering the optimum combination of decrease in energy use balanced with increase in total factory cost. A natural branch exists in the analysis because of the type of pilot-less ignition which is used. As is shown below, the first branch assumes an electric ignition is used in the oven and an electronic ignition is used in the cooktop portion of the range. In the second branch, an electronic ignition is used for both. The annual energy usage and energy factor data presented in Table 1.18 are based on the use of the most recent annual useful cooking energy output values.

Unfortunately, there is insufficient data with regard to energy factors to complete the analysis. However, the main purpose of this analysis was to determine if any advantages could be realized with regard to life-cycle cost and payback. See Section 4.1.3 of Chapter 4 herein for this analysis. The analysis shows that there could be cost savings in the range analysis due to shared costs between the cooktop and oven for the pilot-less ignition and for the installation cost. For instance, in this analysis there is a single cost of $22.50 for the installation of an electrical outlet compared to costs of this amount which are included separately for the cooktop and oven. See Section 1.3.3 for details regarding the installation cost. The analysis shows there is significant reductions in life-cycle costs and payback period by considering a combined installation cost.

Table 1.18 Cost-Efficiency Table for Gas Ranges

GAS COOKTOPS

Energy Efficiency Level	Design No.	Design Option	Total Factory Cost *1990$*	Annual Energy Use Gas *kBtu*	Gas *MMBtu*	Electric *kWh*	Total *MMBtu*	EF
1,2	0	Baseline	89.09	3373	3.373	0.0	3.373	15.6%
3,4	1	0 + Electronic Ignition	101.15	1323	1.323	0.0	1.323	39.9%
	2	1 + Sealed Burner	121.15	1257	1.257	0.0	1.257	42.0%
5	3	2 + Reflective Surface	127.29	1256	1.256	0.0	1.256	42.0%
	4	3 + T'stat Burners	144.22	1256	1.256	0.0	1.256	42.0%

GAS OVENS Non Self-cleaning

Energy Efficiency Level	Design No.	Design Option	Total Factory Cost *1990$*	Annual Energy Use Gas *kBtu*	Gas *MMBtu*	Electric *kWh*	Total *MMBtu*	EF
1,2	0	Baseline	154.80	2982	2.982	0.0	2.982	3.0%
3	1	0 + Electric Glo-bar Ignition	166.86	1408	1.408	34.2	1.524	5.8%
	2	1 + Improve Insulation	170.44	1335	1.335	34.2	1.452	6.1%
4	3	2 + Improve Seals	171.52	1321	1.321	34.2	1.438	6.2%
	4	3 + Forced Convection	193.66	1240	1.240	37.1	1.367	6.5%
	5	4 + Reduced Vent Rate	195.28	1234	1.234	37.1	1.361	6.5%
5	6	5 + Separator	223.54	1233	1.233	37.1	1.359	6.5%
	7	6 + Reduced Conduction Losses	227.17	1227	1.227	37.1	1.353	6.6%
	8	0 + Electronic Spark Ignition	169.80	1524	1.524	0.0	1.524	5.8%

GAS RANGE

Energy Efficiency Level	Design No.	Design Option	Total Factory Cost *1990$*	Annual Energy Use Gas *kBtu*	Gas *MMBtu*	Electric *kWh*	Total *MMBtu*	EF
1,2	0	Baseline	243.89	6354	6.354	0.0	6.354	NA
3	1+2	0 + Ignition: Electric (Oven) / IID (Cktop)	268.01	2731	2.731	34.2	2.847	NA
4	3	1+2+ Improve Insulation	271.59	2658	2.658	34.2	2.775	NA
4	4	3 + Improve Seals	272.67	2644	2.644	34.2	2.761	NA
5	5	4 + Sealed Burner	292.67	2578	2.578	34.2	2.695	NA
5	6	5 + Reflective Surface	298.81	2577	2.577	34.2	2.694	NA
5	7	6 + Forced Convection	320.95	2496	2.496	37.1	2.623	NA
5	8	7 + Reduced Vent Rate	322.57	2490	2.490	37.1	2.617	NA
5	9	8 + Separator	350.83	2488	2.488	37.1	2.615	NA
5+	10	9 + Reduce Conduction Losses	354.46	2482	2.482	37.1	2.609	NA
5+	11	10 + T'stat Burners	371.39	2482	2.482	37.1	2.609	NA
3	12	0 + Both IID Ignitions (Oven & Cktop)	264.95	2847	2.847	0.0	2.847	NA
4	13	12 + Improve Insulation	268.53	2775	2.775	0.0	2.775	NA
4	14	13 + Improve Seals	269.61	2760	2.760	0.0	2.760	NA
5	15	14 + Sealed Burner	289.61	2695	2.695	0.0	2.695	NA
5	16	15 + Reflective Surface	295.75	2693	2.693	0.0	2.693	NA
5	17	16 + Forced Convection	317.89	2613	2.613	0.0	2.613	NA
5	18	17 + Reduced Vent Rate	319.51	2606	2.606	0.0	2.606	NA
5	19	18 + Separator	347.76	2605	2.605	0.0	2.605	NA
5+	20	19 + Reduce Conduction Losses	351.40	2599	2.599	0.0	2.599	NA
5+	21	20 + T'stat Burners	368.33	2599	2.599	0.0	2.599	NA

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CHAPTER 2. BASE CASE FORECASTS: KITCHEN RANGES AND OVENS

The impacts of federal energy efficiency levels are calculated by comparing projected U.S. residential energy consumption with and without the levels. The cases without energy efficiency levels are referred to as *base case projections*. These base case projections are compared to projections of conditions that would be likely prevail if energy efficiency levels were enacted (see Chapter 3). The difference between the two projections is defined as the incremental impact of energy efficiency levels.

Projections are made for a number of demographic, economic, and energy variables, including energy prices, household income, housing stock, housing starts, mix of house types (single-family, multi-family, mobile homes), building shell thermal characteristics, appliance purchases, equipment prices, unit energy consumption, and aggregate residential energy consumption by fuel type.

2.1 DEMOGRAPHIC AND ECONOMIC ASSUMPTIONS

The demographic and economic assumptions are described in Volume 1, *Methodology*, Chapter 5 of this Technical Support Document (TSD).

2.2 AVERAGE EQUIPMENT LIFETIME

A distribution of equipment lifetimes, or the rates at which appliances retire as a function of years since purchase, are determined by analyzing historical shipments reported by the industry trade association. Table 2.1 shows the average lifetimes.

Table 2.1 Average Equipment Lifetime (Years) of Kitchen Cooktops and Ovens

	Years	Source
Electric Cooktops	19.0	LBNL
Gas Cooktops	19.0	LBNL
Electric Ovens	19.0	LBNL
Gas Ovens	19.0	LBNL
Microwave Ovens	10.0	LBNL

2.3 BASE CASE PROJECTIONS

This section contains projections of unit energy consumption of new appliances, annual appliance installations, annual residential energy consumption, and price of purchased appliances.

2.3.1 New Appliance Unit Energy Consumptions

Annual unit energy consumption (UEC) of new appliances is projected based upon a set of designs available (each design characterized by a purchase price and an energy-efficiency factor or UEC), and a market discount rate (derived from implicit decision-making in recent purchase decisions for the product). Average efficiency factors for new units sold in past years were not available. The LBNL-REM produces projections of annual energy consumption of new appliances after 1980. Tables 2.2a and 2.2b show the trends in efficiency and annual unit energy consumption.

Table 2.2a Base Case Projection of Average Energy Factors for New Cooktops and Ovens

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	0.738	0.193	0.101	0.039	0.557
1993	0.738	0.379	0.101	0.052	0.557
1996	0.738	0.379	0.101	0.052	0.557
1999	0.738	0.379	0.101	0.052	0.557
2030	0.765	0.379	0.101	0.052	0.557

Source: LBNL-REM (1980-2030).

Table 2.2b Base Case Projection of Unit Energy Consumption for New Cooktops and Ovens

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
	(kWh)	(MMBtu)	(kWh)	(MMBtu)	(kWh)
1981	234.5	3.06	291.1	2.43	143.2
1993	234.5	1.49	291.1	1.82	143.2
1996	234.5	1.49	291.1	1.82	143.2
1999	234.5	1.49	291.1	1.82	143.2
2030	226.4	1.49	291.1	1.82	143.2

Source: LBNL-REM (1980-2030).

2.3.1.1 Efficiency Distributions

Because this product is not part of the federal appliance labeling program, no distribution is available; instead, all shipments in each year are taken to be of a single design option.

2.3.1.2 Usage

The relative usage expressing hours of operation per year as a relative index with a value of 1.0 in the base year (1980) is shown in Table 2.3. Usage of electric cooking is projected to increase after 1990. Usage of gas cooking also increases, until 2000, after which increased gas prices cause a decrease. Usage is a function of operating expense and income.

Table 2.3 Projected Average Usage of Cooktops and Ovens

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	0.97	1.00	0.97	1.00	0.97
1993	0.95	1.05	0.95	1.04	0.95
1996	0.95	1.06	0.95	1.05	0.95
1999	0.96	1.08	0.96	1.06	0.96
2030	0.96	0.96	0.96	1.05	0.96

Source: LBNL-REM (1980-2030).

2.3.2 Annual U.S. Appliance Installations

The market for appliances is seen as having two segments: new construction and existing housing. All new households are considered eligible to purchase each appliance. The pool of potential purchasers among existing households each year is defined as households that retired a unit that year, plus a fraction of households that did not previously own the product.

The initial (1980) fraction of new (and of existing) households expected to purchase each product and fuel type is specified as input to LBNL-REM. LBNL-REM produces projected fractions, for each year, of new households (and of existing households) that purchase the product. The projection is based on market share elasticities with respect to income, equipment price, and annual operating expense. Market share elasticities are given in Appendix B.

The projection for the period 1981-1990 is calibrated to reasonable agreement with available data, including domestic shipments (from published trade asssociation data) and surveys of appliance ownership, e.g., from DOE/EIA RECS (1) and the Bureau of the Census.

Tables 2.4 and 2.5 show the significant trends in the installation and saturation of this product.

Table 2.4 Annual Installations of New Cooktops and Ovens in U.S. Households (Millions)

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1981	2.74	1.73	2.59	1.86	7.60
1993	3.65	2.40	3.36	2.61	9.13
1996	3.58	2.27	3.30	2.45	8.65
1999	3.31	2.05	3.09	2.22	8.99
2030	4.74	3.19	4.45	3.41	13.22

Table 2.5 Percent of Occupied U.S. Housing Units Having Cooktops and Ovens

Year	Electric Cooktop (%)	Gas Cooktop (%)	Electric Oven (%)	Gas Oven (%)	Microwave Oven
1981	54	46	55	42	26
1993	59	40	57	41	77
1996	60	39	57	41	82
1999	61	39	57	41	85
2030	60	40	56	43	97

Source: LBNL-REM (1980-2030).

2.3.3 U.S. Residential Energy Consumption

U.S. residential energy consumption for this product is calculated each year as the product of: number of occupied households; fraction of households owning the appliance; average unit energy consumption; and usage.

Table 2.6 shows the projected U.S. energy consumption, expressed in quadrillion Btu of primary energy using a conversion factor for electricity of one Kwh per 11,500 Btu.

Table 2.6 U.S. Residential Energy Consumption for Cooktops and Ovens (Quadrillion Btu, Primary Energy)

	Cooktop		Oven		Microwave Oven	
Year	Electricity	Gas	Electricity	Gas	Electricity	Total
1981	0.12	0.13	0.15	0.09	0.03	0.51
1993	0.15	0.10	0.18	0.09	0.12	0.63
1996	0.15	0.09	0.18	0.08	0.13	0.63
1999	0.16	0.08	0.19	0.08	0.14	0.65
2030	0.20	0.08	0.26	0.10	0.20	0.84

Source: LBNL-REM.

2.3.4 Price of Purchased Appliances

Prices of new units increase over time as energy-efficiency improvements are incorporated. Table 2.7 shows projected shipment-weighted average prices.

Table 2.7 Average Price of New Cooktops and Ovens in U.S. Households (1990 dollars)

Year	Electric Cooktop	Gas Cooktop	Electric Oven	Gas Oven	Microwave Oven
1980	194	225	529	568	189
1993	194	258	529	587	189
1996	194	258	529	587	189
1999	194	258	529	587	189
2030	198	258	529	587	189

Source: LBNL-REM.

2.4 SENSITIVITY ANALYSIS OF THE BASE CASE

The sensitivity cases selected are defined as follows:

1. *Lower Equipment Price.* The price of the baseline unit and the incremental price associated with each engineering level is decreased by the estimated uncertainty interval.

2. *Higher Equipment Price*. The price of the baseline unit and the incremental price associated with each engineering level is increased by the estimated uncertainty interval.

3. *Lower Energy Price*. Assume lower energy prices. Starting from 1996 to 2030, electricity prices are 3% lower while gas and distillate prices are 5% lower than those in the *Annual Energy Outlook 1995* (2) forecast.

4. *Higher Energy Price*. Assume higher energy prices. Starting from 1996 to 2030, electricity prices are 3% higher while gas and distillate prices are 5% higher than those in the *Annual Energy Outlook 1995* forecast.

5. *High Equipment Efficiency*. Assume continuing future improvement in appliance efficiencies at a rate of 2% per year.

6. *Market Discount Rates Decline*. Assume that market discount rates used to determine future efficiency choices are declining over time by 2% per year, i.e., efficiency improvements appear in the marketplace sooner.

The results of these six sensitivity cases are presented in the following tables. Tables 2.8a to 2.8e show how the average price varies. Tables 2.9a to 2.9e show the differences in unit energy consumption or efficiency. The first line of these tables give the results of the reference case described in the previous section; the rest of the lines give the corresponding results of the sensitivity cases listed above.

Table 2.8a Average Purchase Price of New Electric Cooktops (1990 Dollars)

Year:	1981	1993	1996	1999	2030
Reference	194	194	194	194	198
1	146	149	149	149	149
2	242	242	242	242	242
3	194	194	194	194	198
4	194	194	194	194	198
5	194	277	310	321	321
6	194	194	198	198	198

Table 2.8b Average Purchase Price of New Gas Cooktops (1990 Dollars)

Year:	1981	1993	1996	1999	2030
Reference	225	258	258	258	258
1	203	235	235	235	235
2	247	281	281	281	281
3	225	258	258	258	258
4	225	258	258	258	258
5	225	261	297	313	313
6	225	258	258	258	258

Table 2.8c Average Purchase Price of New Electric Ovens (1990 Dollars)

Year:	1981	1993	1996	1999	2030
Reference	529	529	529	529	529
1	476	476	476	476	476
2	581	581	581	581	581
3	529	529	529	529	529
4	529	529	529	529	529
5	529	541	568	597	868
6	529	529	529	529	530

Table 2.8d Average Purchase Price of New Gas Ovens (1990 Dollars)

Year:	1981	1993	1996	1999	2030
Reference	568	587	587	587	587
1	457	475	475	475	475
2	679	699	699	699	699
3	568	587	587	587	587
4	568	587	587	587	587
5	568	591	598	612	756
6	568	587	587	587	594

Table 2.8e Average Purchase Price of New Microwave Ovens (1990 Dollars)

Year:	1981	1993	1996	1999	2030
Reference	189	189	189	189	189
1	151	151	151	151	151
2	227	227	227	227	227
3	189	189	189	189	189
4	189	189	189	189	189
5	189	194	255	255	255
6	189	189	189	189	189

Table 2.9a Average Unit Energy Consumption of New Electric Cooktops (kWh/Year)

Year:	1981	1993	1996	1999	2030
Reference	234.5	234.5	234.5	234.5	226.4
1	234.5	226.4	226.4	226.4	226.4
2	234.5	234.5	234.5	234.5	234.5
3	234.5	234.5	234.5	234.5	226.4
4	234.5	234.5	234.5	234.5	226.4
5	234.5	225.7	221.2	220.4	220.4
6	234.5	234.5	226.4	226.4	226.4

Table 2.9b Average Unit Energy Consumption of New Gas Cooktops (MMBtu/year)

Year:	1981	1993	1996	1999	2030
Reference	3.06	1.49	1.49	1.49	1.49
1	3.06	1.49	1.49	1.49	1.49
2	3.06	1.49	1.49	1.49	1.49
3	3.06	1.49	1.49	1.49	1.49
4	3.06	1.49	1.49	1.49	1.49
5	3.06	1.36	1.26	1.26	1.26
6	3.06	1.49	1.49	1.49	1.49

Table 2.9c Average Unit Energy Consumption of New Electric Ovens (kWh/Year)

Year:	1981	1993	1996	1999	2030
Reference	291.1	291.1	291.1	291.1	291.1
1	291.1	285.9	285.9	285.9	285.9
2	291.1	291.1	291.1	291.1	291.1
3	291.1	291.1	291.1	291.1	291.1
4	291.1	291.1	291.1	291.1	291.1
5	291.1	281.4	266.8	253.8	191.2
6	291.1	291.1	291.1	291.1	285.9

Table 2.9d Average Unit Energy Consumption of New Gas Ovens (MMBtu/year)

Year:	1981	1993	1996	1999	2030
Reference	2.43	1.82	1.82	1.82	1.82
1	2.43	1.82	1.82	1.82	1.82
2	2.43	1.82	1.82	1.82	1.82
3	2.43	1.82	1.82	1.82	1.82
4	2.43	1.82	1.82	1.82	1.82
5	2.43	1.72	1.57	1.46	1.36
6	2.43	1.82	1.82	1..82	1.56

Table 2.9e Average Unit Energy Consumption of New Microwave Ovens (kWh/year)

Year:	1981	1993	1996	1999	2030
Reference	143.2	143.2	143.2	143.2	143.2
1	143.2	143.2	143.2	143.2	143.2
2	143.2	143.2	143.2	143.2	143.2
3	143.2	143.2	143.2	143.2	143.2
4	143.2	143.2	143.2	143.2	143.2
5	143.2	137.7	132.4	132.4	132.4
6	143.2	143.2	143.2	143.2	143.2

Source: LBNL-REM.

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CHAPTER 3. PROJECTED NATIONAL IMPACTS OF ENERGY EFFICIENCY LEVELS: KITCHEN RANGES AND OVENS

The LBNL Residential Energy Model (LBNL-REM) projects a number of economic and energy-use variables that are used to assess the impact of proposed energy efficiency levels on consumers, electric utilities, and appliance manufacturers. This chapter presents projections from the model, which assume various energy efficiency levels.

The principal outputs from the LBNL-REM for each year are:

- unit equipment price and operating expense by product,
- projected annual shipments of residential appliances,
- energy consumption by end use and fuel, and
- differences in these quantities between a base case and each energy efficiency level.

These outputs are calculated for each year and accumulated over a period of time, i.e., 1999-2030. Energy savings are given for each year from implementation of energy efficiency levels to the end of the period. Net present value of the energy efficiency levels is evaluated for each regulated product and for the end use(s) comprising the regulated and competing products. The sensitivity of the outputs to the key assumptions and data is analyzed; the results of this analysis are also presented.

Section 3.1 presents the energy efficiency levels analyzed. Section 3.2 presents the historical and projected energy consumption, including unit energy consumption for new purchases, and total national energy consumption. Section 3.3 presents historical and projected annual installations. Section 3.4 presents purchase prices and Section 3.5 presents net present value.

An overview of the general LBNL-REM methodology and demographic assumptions is in Volume 1 of this Technical Support Document (TSD). Product-specific input data are described in Appendix C of this volume.

3.1 ENERGY EFFICIENCY LEVELS

Table 3.1 shows the correspondence between the energy efficiency levels, the engineering design levels, and the associated unit energy consumption (UEC).

CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

The effect of energy efficiency levels on individual consumers includes a change in operating expense (usually a decrease) and a change in purchase price (usually an increase). The net effect is analyzed by calculating the life-cycle cost, using the engineering data (Chapter 1) for energy consumption and equipment price, and assuming an energy price for 1999. Section 4.1 presents the life-cycle costs (LCC) for each design option. The results are displayed as graphs and as tables of values. Section 4.2 presents the effect of different assumptions on the life-cycle cost calculations. Sections 4.3 through 4.5 show the impacts of efficiency levels on consumers.

The *difference* due to energy efficiency levels is calculated (Sections 4.3 to 4.5) after a base case forecast is made (see Chapter 2). The base case forecast accounts for market-based shifts in efficiency and usage that are projected to occur independently of efficiency levels. Then only those appliance purchasers who are impacted by efficiency levels (i.e., those who would have chosen a design eliminated by the levels) are included in calculating the impact of efficiency levels on consumers. The impact of energy efficiency levels is expressed by three measures:

- Section 4.3: Change in Life-Cycle Cost (LCC), and
- Section 4.4: Payback Period (PBP),
- Section 4.5: Cost of Conserved Energy (CCE).

4.1 LIFE-CYCLE COST FOR DESIGN OPTIONS

The LCC is the sum of the installed consumer cost (*ICC*) and the present value of operating expenses (*OE*) discounted over the lifetime (*N*) of the appliance.

$$LCC = ICC + \sum_{t=1}^{N} \frac{OE_t}{(1 + r)^t} \tag{4.1}$$

If operating expenses are constant over time, Eq. 4.1 simplifies to:

$$LCC = ICC + PWF \cdot OE, \tag{4.2}$$

where the present worth factor is defined as:

CHAPTER 5. IMPACTS OF ENERGY EFFICIENCY LEVELS ON THE MANUFACTURERS OF KITCHEN RANGES AND OVENS

This chapter describes estimates of the impacts of energy efficiency levels on manufacturers of kitchen ranges and ovens. These estimates are based on the Lawrence Berkeley National Laboratory Manufacturer Analysis Model (LBNL-MAM) which consists of the former LBL-Manufacturer Impact Model and the Government Regulatory Impact Model developed by Arthur D. Little Consulting Company. The LBNL-MAM collects into one spreadsheet all calculations necessary to determine the impact of energy effciency levels on an industry's profitability and scale of operation. A complete description of the LBNL-MAM and its inputs and outputs for the kitchen ranges and ovens industry analysis are included in Volume 1: Appendix C.

Kitchen ranges and ovens were analyzed at five different energy efficiency levels. In each case it is assumed that the efficiency levels would be just stringent enough to induce manufacturers to use all engineering design options up through the one listed as achieving the desired energy efficiency. For a complete description of these design options, see the Engineering Analysis in Chapter 1.

5.1 LONG-RUN IMPACTS

Cooktops

The analysis shows that compared to the base case, the kitchen cooktop industry is likely to experience a decrease in return on equity (ROE) at energy efficiency levels 2 through 5 and no change in ROE at level 1. At efficiency level 2 there is approximately a 66% chance of a decrease in ROE, with an expected decrease of 0.07%. At efficiency level 3 there is approximately a 61% chance of a decrease in ROE, with an expected decrease of 0.06%. At efficiency level 4 there is approximately a 58% chance of a decrease in ROE, with an expected decrease of 0.05%. At efficiency level 5 there is approximately a 57% chance of a decrease in ROE, with an expected decrease of 0.42%. These results are shown in Table 5.1. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

Ovens

The analysis shows that compared to the base case, the kitchen oven industry is likely to experience a decrease in return on equity (ROE) at all five energy efficiency levels. At efficiency level 1, there is approximately a 61% chance of a decrease in ROE, with an expected decrease of 0.02%. At efficiency level 2 there is approximately a 59% chance of a decrease in ROE, with an expected decrease of 0.02%. At efficiency level 3 there is approximately a 77% chance of a decrease in ROE, with an expected decrease of 0.17%. At efficiency level 4 there is approximately a 54% chance of a decrease in ROE, with an expected decrease of 0.19%. At efficiency level 5 there is approximately

CHAPTER 6. IMPACTS OF ENERGY EFFICIENCY LEVELS ON ELECTRIC UTILITIES: RANGES AND OVENS

6.1 INTRODUCTION

Appliance efficiency energy efficiency levels have four principal effects on electric utilities: 1) they allow utilities to avoid fuel and other operating costs because less electricity needs to be generated, 2) they may allow utilities to defer construction of new generating capacity, 3) they may allow utilities to defer construction of new or upgraded transmission and distribution (T&D) capacity, and 4) they reduce revenues from electricity sales. The second section of this chapter presents the results of the avoided cost calculations. The third section presents the expected peak load and reliability savings for the analyzed efficiency levels. The fourth section presents the results of the revenue loss calculation. More details on methodology may be found in Appendix E of Volume 1.

6.2 AVOIDED ENERGY AND AVOIDED CAPACITY COSTS

Table 6.1 shows avoided energy and capacity cost rates for electricity savings from ranges and ovens. The avoided cost rate per million Btu (MMBtu) of avoided energy consumption is the same for all three products because the duty cycle of these three appliances is so similar.[1] As explained in Appendix E of Volume 1, the avoided capacity cost component implicitly contains the costs avoided when power plants are deferred or canceled, and it also contains avoided T&D capital costs. These avoided costs represent a simple summary of the utility analysis and they are a measure of the societal benefit of the electricity saved in each year.

6.3 PEAK LOAD AND CAPACITY REDUCTIONS

Tables 6.2 to 6.4 show peak load reductions for cooktops, ovens, and microwaves for all efficiency levels and Tables 6.5 to 6.7 show capacity savings. The base case peak load (second column of Tables 6.2 through 6.4) represents coincident peak load of all such appliances in the residential sector.

The total peak demand and the savings are calculated using the appropriate conservation load factors, a T&D loss factor of 7.5%, and estimates of energy consumption calculated using the LBNL-REM. The concept of a conservation load factor is explained in Appendix E of Volume 1. It allows estimates of energy savings to be converted to estimates of capacity savings. Capacity savings are peak load savings in regions that need additional capacity, multiplied by 1.2 to account for the reserve margin needed for adequate reliability.

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[1] Fuel price forecasts for the period 1990 to 2010 are taken from the DOE/EIA *Annual Energy Outlook, 1995* (DOE/EIA-0383(95)). The forecasts for years after 2010 were linearly extrapolated.

CHAPTER 7. ENVIRONMENTAL EFFECTS: RANGES AND OVENS

7.1 INTRODUCTION

The environmental effects of candidate energy-efficiency performance requirements for cooking appliances are discussed in this chapter. The results of the analysis are presented for each potential energy efficiency level for each of the three cooking appliances (cooktops, conventional ovens, and microwave ovens). Each measure of possible environmental change is an alternative action, and they are compared to expected environmental effects if no new efficiency levels for cooking appliances are finalized, i.e., the "no action" alternative.

The primary environmental concern addressed in this chapter is the emissions from fossil-fueled electricity generation. All of the design options for the three cooking appliances result in decreased electricity use and, therefore, a reduction in power plant emissions. The proposed efficiency levels will generally decrease air pollution by decreasing future energy demand. The greatest decreases in air pollution will be for sulfur oxides, listed in equivalent weight of sulfur dioxide, SO_2. Reductions of nitrogen oxides and carbon dioxide also occur and are listed by weight of NO_x and CO_2, respectively. CO_2 emissions from fossil-fuel burning are considered an environmental hazard because it contributes to the "greenhouse effect" by trapping heat energy emitted from the earth as infrared radiation. The "greenhouse effect" is expected to gradually raise the mean global temperature. Since cooktops and conventional ovens include product classes that consume fuel (i.e., gas cooktops and ovens), design options will also reduce in-home fuel consumption, resulting in lower emissions from these fuel-burning appliances.

For a detailed description of the methodology that was used in estimating the environmental impacts, please refer to the Environmental Assessment in Volume 1 of this Technical Support Document.

7.2 RESULTS

Tables 7.1 through 7.15 indicate the degree to which CO_2, SO_2, and No_x emissions will be changed by imposing efficiency levels on cooking appliances. A table is presented for each of the appliances' energy efficiency levels. The appliances have been analyzed separately in order to determine emission changes resulting from each of their prospective energy efficiency levels. Tables 7.1 to 7.15 detail the changes that occur to each of the three emissions, i.e. CO_2, SO_2, and NO_x, through the imposition of an appliance's specific energy efficiency levels. The tables includes the following information for a specific year between 1996 and 2030: the amount of emission abated from both power plant and from in-house generation, the net change in the emissions, and the percent the net change comprises of total U.S. power plant emissions. Also included are the cumulative changes of each pollutant between the years 1998 and 2030.

Decreases in the amounts of CO_2, SO_2, and NO_x are presented for cooktops, conventional ovens, and microwave ovens. Energy efficiency levels 1 through 5 for cooktops are summarized in Tables 7.1 through 7.5, energy

APPENDIX A. ENGINEERING ANALYSIS - SUPPORTING DOCUMENTATION

A.1 ANNUAL USEFUL COOKING ENERGY OUTPUT FROM PROPOSED TEST PROCEDURE

The annual useful cooking energy output is the cooking energy delivered to the food over the course of a year. It is used in the DOE test procedure calculations to calculate annual energy consumption for cooktops and ovens. However, estimates of annual cooking energy consumption have declined since the DOE test procedure was implemented in 1978 (1) and later amended in 1979 (2). This is a result of changing household demographics and cooking patterns. The results of several studies of cooking energy consumption for gas and electricity are shown in Figures A.1 and A.2. These results are included in this analysis and are used to develop annual useful cooking energy output values which are lower than those found in the existing DOE test procedure. In 1995, these lower values for the annual useful cooking energy output were proposed by DOE to replace the existing test procedure values for cooktops and ovens (3). The data displayed in Figures A.1 and A.2 are listed in Tables A.1 and A.2, respectively. The sources of the data are described in Section A.1.1. To emphasize, it is these data which were used to support the changes to the annual useful cooking energy output in DOE's Proposed Rule for the kichen range and oven test procedure in 1995 (4).

As will be discussed in Section A.2, further studies have been analyzed which show even lower annual energy usage for kitchen ranges and ovens. From this data even lower annual useful cooking energy output values are determined. It is the most recent annual usage data which has been incorporated into all the analyses of this Technical Support Document (TSD) including the engineering analysis (Volume 2, Chapter 1), the consumer forecasting analysis (Volume 2, Chapters 2 and 3), the life-cycle cost and payback analysis (Volume 2, Chapter 4), the manufacturer impact analysis (Volume 2, Chapter 5), the utility analysis (Volume 2, Chapter 6), and the environmental analysis (Volume 2, Chapter 7). It should be noted that the engineering analysis in Chapter 1 and the payback period analysis in Chapter 4 also present results based on determining annual energy usage with annual useful cooking energy output values prescribed by DOE's proposed test procedure.

Figure A.1 Annual Electric Cooking Energy Consumption

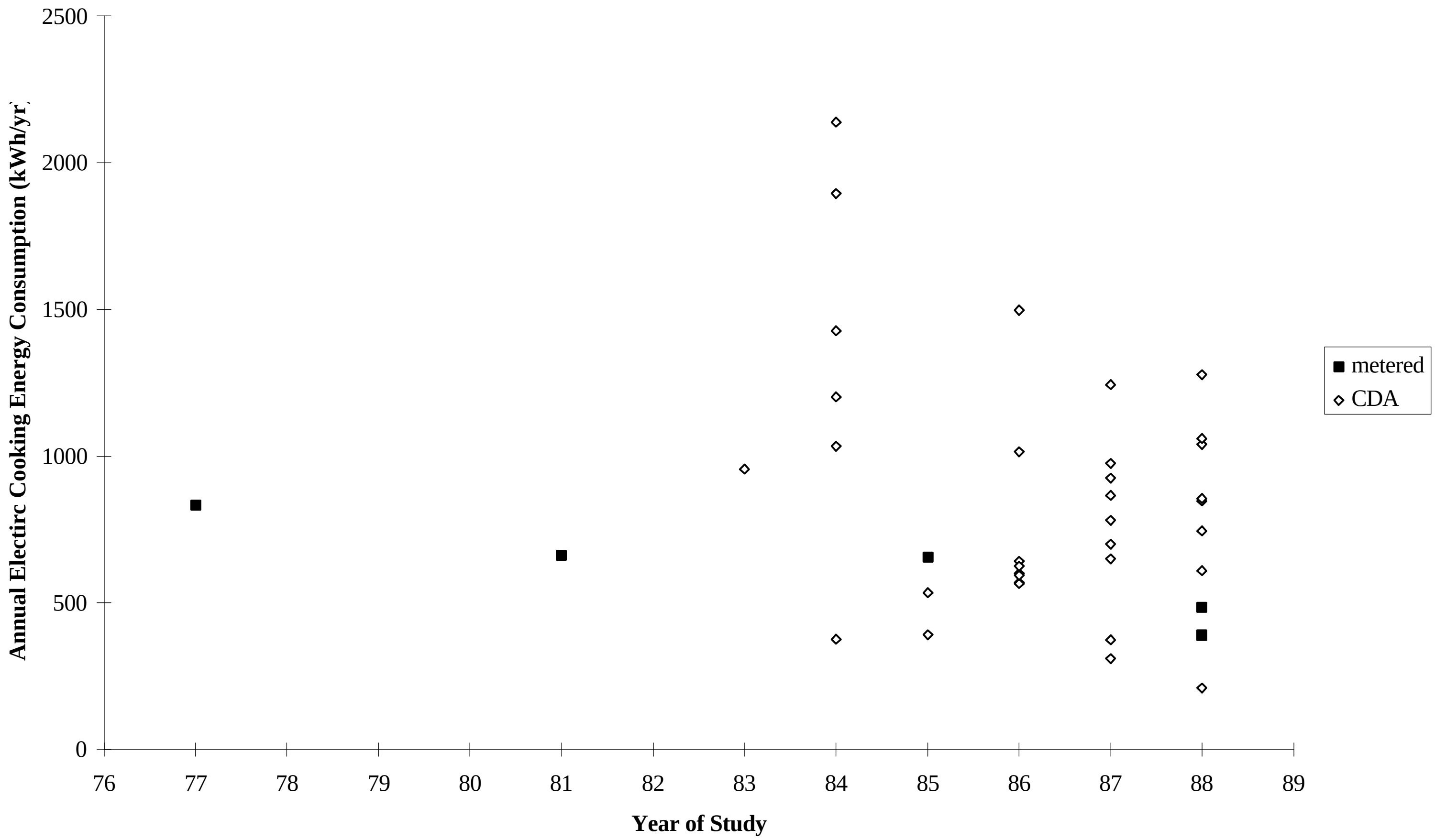

Figure A.2 Annual Gas Cooking Energy Consumption

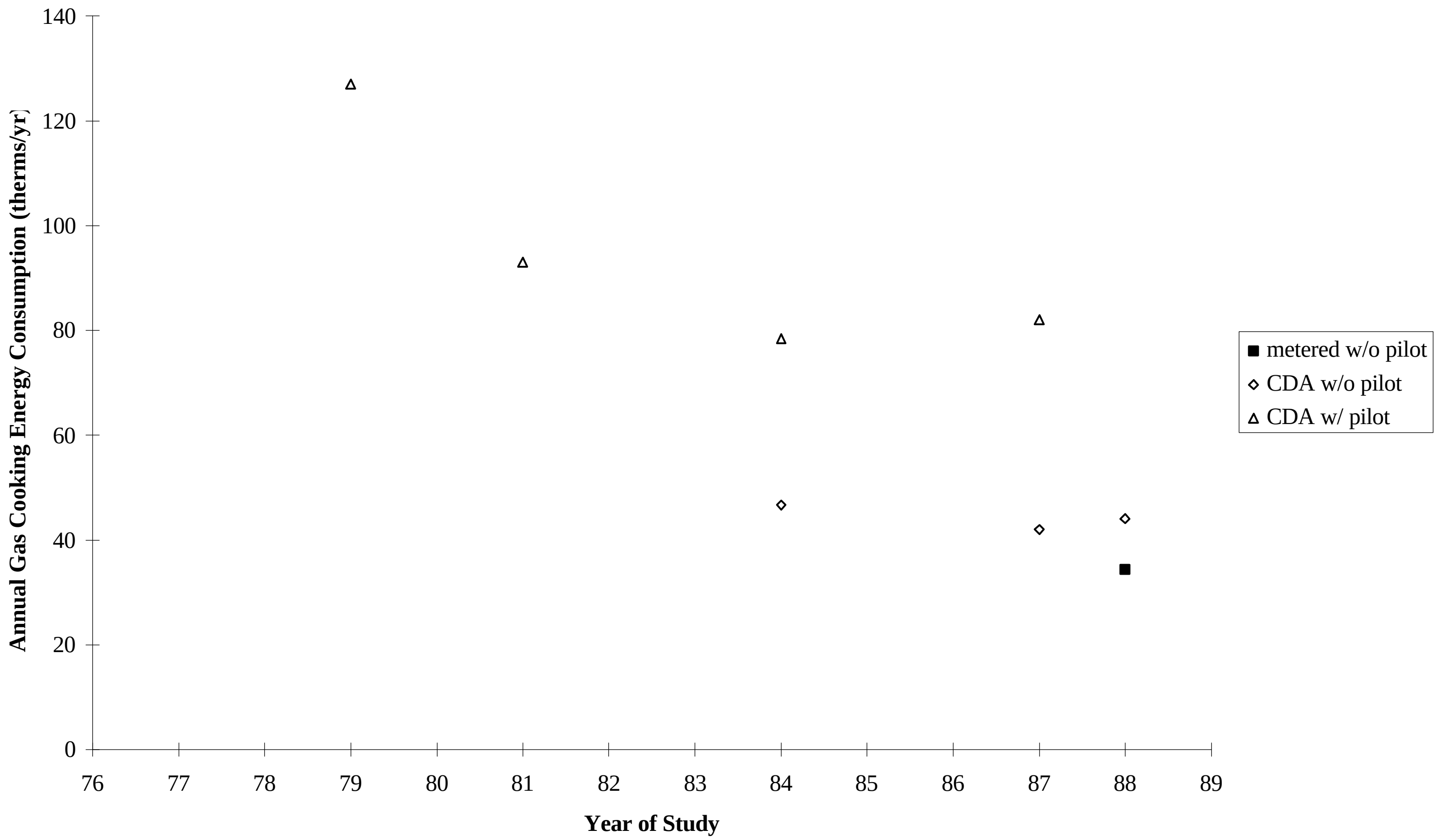

Table A.1 Annual Electric Cooking Energy Consumption[1]

Source	Year	Cooktop	Oven	Range	Units	Type
SCE	88			390.0	kWh	meter
Sierra	88			484.0	kWh	meter
PG&E	85	322.0	334.0	656.0	kWh	meter
Potomac	81			662.0	kWh	meter
MRI	77	589.8	496.8	833.3	kWh	meter
AEP	88			1040.0	kWh	CDA
BG&E	88			610.0	kWh	CDA
BSG/XENERGY	88			210.0	kWh	CDA
Sierra	88			848.0	kWh	CDA
TNP	88			1060.0	kWh	CDA
NMPC	88			1278.0	kWh	CDA
LILCO	88			745.0	kWh	CDA
PSE&G	88			855.0	kWh	CDA
CEC	87			650.0	kWh	CDA
CommEd	87			310.0	kWh	CDA
El Paso	87			866.0	kWh	CDA
JCP&L	87			926.0	kWh	CDA
MetEd	87			782.0	kWh	CDA
PG&E	87			375.0	kWh	CDA
VEPCO	87			1243.0	kWh	CDA
ACEEE	87			700.0	kWh	CDA
REEPS	87			976.0	kWh	CDA
FP&L	86			568.0	kWh	CDA
Gulf	86			1015.0	kWh	CDA
NPC	86			642.0	kWh	CDA
NYSEG	86			600.0	kWh	CDA
PG&E	86			625.0	kWh	CDA
PG&Ea	86			566.0	kWh	CDA
RG&E	86			593.0	kWh	CDA
TVA	86			1498.0	kWh	CDA
PG&E	85			392.0	kWh	CDA
SDG&E	85			534.0	kWh	CDA
AP&L	84			1896.0	kWh	CDA
LP&L	84			1202.0	kWh	CDA
MP&L	84			2138.0	kWh	CDA
MPC	84			1034.0	kWh	CDA
NOPS	84			1427.0	kWh	CDA
SDG&E	84			376.0	kWh	CDA
APC	83			955.0	kWh	CDA

[1] Due to the age of the data (from the years 1977 to 1988), the electric self-cleaning ovens represented by the data are assumed to be operated with the same self-clean cycles as in the existing DOE test procedure (11 cycles per year).

Table A.2 Annual Gas Cooking Energy Consumption[2]

Source	Year	Cooktop	Oven	Range	Units	Type	Pilot
SCE	88			34.4	therms	meter	no
BSG/XENERGY	88			44.0	therms	CDA	no
CEC	87			42.0	therms	CDA	no
SoCal	84			46.7	therms	CDA	no
REEPS	87			82.0	therms	CDA	yes
SoCal	84			78.4	therms	CDA	yes
SoCal	81			93.0	therms	CDA	yes
SoCal	79			127.0	therms	CDA	yes

The average annual useful cooking energy output for DOE's proposed test procedure was calculated from the following: 1) the above utility studies of annual energy consumption (shown in Tables A.1 and A.2), 2) DOE test procedure assumptions, 3) baseline cooktop and oven cooking efficiencies (as assumed in the technical analysis in support of the minimum efficiency standards proposed by DOE on March 4, 1994 for kitchen ranges and ovens (5)), and 4) market shares of oven types.

Gas Cooking

The calculations for gas cooking were based on an average annual cooking energy consumption of 41.8 therms reported by four recent studies[3] done in California. Because of the building code in California, the cooking equipment in these studies were assumed to have no standing pilot lights. Only these studies were used in the calculation to avoid having to correct for pilot light consumption. The average annual gas cooking energy consumption was assumed to equal the sales weighted average of standard and self-cleaning oven energy consumption plus the cooktop energy consumption.

$$\begin{aligned} UEC_{gas\ cooking} &= 41.8\ therms \\ &= MSg_{sc} \bullet UEC_{gas\ oven\ sc} \\ &+ (1 - MSg_{sc}) \bullet UEC_{gas\ oven} \\ &+ UEC_{gas\ cooktop} \end{aligned} \tag{A.1}$$

[2] Due to the age of the data (from the years 1979 to 1988), the gas self-cleaning ovens represented by the data are assumed to be operated with the same self-clean cycles as in the existing DOE test procedure (7 cycles per year).

[3] These are the studies listed as SCE '88, BSG/Xenergy '88, CEC '87, SoCal '84 for gas in Table A.2.

where,

MSg_{sc} = the market share of gas ovens that are self-cleaning, 23.74% (6),

$UEC_{gas\ oven\ sc}$ = unit energy consumption for self-cleaning gas ovens,

$UEC_{gas\ oven}$ = unit energy consumption for standard gas ovens,

$UEC_{gas\ cooktop}$ = unit energy consumption for gas cooktops.

The average energy consumption of self-cleaning ovens was estimated as a fraction of the energy consumption of a standard gas oven plus the self-cleaning energy. The average energy consumption of cooktops was estimated as a fraction of the energy consumption of standard ovens. These fractions were from the ratios of energy consumption in the DOE test procedure. This was done to determine unit energy consumption of self-cleaning ovens and cooktops as a function of the unit energy consumption of the standard gas oven. The formulas for this are:

$$UEC_{gas\ oven\ sc} = Rg_{sc\ std} \bullet UEC_{gas\ oven} + E_{gs} \bullet S_g \qquad (A.2)$$

and,

$$UEC_{gas\ cooktop} = Rg_{ct\ std} \bullet UEC_{gas\ oven} \qquad (A.3)$$

where,

$Rg_{sc\ std}$ = the ratio of self-cleaning gas oven cooking energy to standard gas oven cooking energy,

$Rg_{ct\ std}$ = the ratio of gas cooktop cooking energy to standard gas oven cooking energy,

E_{gs} = typical self-cleaning energy consumption per cycle for gas self-cleaning ovens, 0.459 therms,

S_g = number of self-clean cycles per year for gas ovens, 7 from DOE (7)[4].

For the purposes of calculating these ratios, the self-cleaning gas oven cooking energy, the gas cooktop cooking energy, and the standard gas oven cooking energy were calculated as the DOE annual useful cooking energy output divided by the baseline cooking efficiency reported in the

[4] For purposes of calculating a revised value for the annual useful cooking energy output for the proposed DOE test procedure, the number of self-clean cycles was assumed to be 7 for gas ovens. As reported in the Executive Summary of Volume 2 of this TSD, more recent data indicates that the number of self-clean cycles should be 4. But for the years in which the data used in these calculations are based (1984 through 1988), 7 self-clean cycles are assumed to be a more representative value.

cost/efficiency tables (Chapter 1, Sections 1.3.3 and 1.4.3). This assumes the ratio of annual useful cooking energy output for cooktops compared to ovens has not changed significantly.

$$Rg_{sc\ std} = \frac{(Oo_{DOE}\ /\ EFFgo_{SC})}{(Oo_{DOE}\ /\ EFFgo_{std})} = 0.827 \tag{A.4}$$

$$Rg_{ct\ std} = \frac{(Oct_{DOE}\ /\ EFFg_{ct})}{(Oo_{DOE}\ /\ EFFgo_{std})} = 0.872 \tag{A.5}$$

where,

Oo_{DOE} = the annual useful cooking energy output for ovens according to the old DOE test procedure (8), 1.607 therms,

Oct_{DOE} = the annual useful cooking energy output for cooktops according to the old DOE test procedure (9), 9.475 therms,

$EFFgo_{SC}$ = the cooking efficiency of the baseline self-cleaning gas oven, from the cost/efficiency table, 7.13%,

$EFFgo_{std}$ = the cooking efficiency of the baseline standard gas oven, from the cost/efficiency table, 5.9%,

$EFFg_{ct}$ = the cooking efficiency of the baseline gas cooktop, from the cost/efficiency table, 39.9%.

At this point Eq. A.1 for the unit energy consumption for gas cooking can be rewritten so the only unknown variable is the unit energy consumption of a standard gas oven. This is done as follows:

$$\begin{aligned} EC_{gas\ cooking} = {} & MSg_{sc} \bullet (Rg_{sc} \bullet UEC_{gas\ oven} + Egs \bullet Sg \\ & + (1 - MSg_{sc}) \bullet UEC_{gas\ oven} \\ & + Rg_{ct\ std} \bullet UEC_{gas\ oven} \end{aligned} \tag{A.6}$$

Solving this equation for the unit energy consumption of standard gas ovens yields 21.1 therms, as shown in the following equation,

$$\text{ıs oven} = \frac{UEC_{gas\ cooking} - Egs \bullet Sg}{(MSg_{sc} \bullet (Rg_{sc\ std} - 1) + Rg_{ct\ std} + 1)} = 21.1\ th \qquad (A.7)$$

The unit energy consumption of the standard gas oven is the annual useful oven cooking energy output divided by the efficiency of the average standard gas ove
n. Using the baseline efficiency from the cost/efficiency table and solving for the annual useful oven cooking energy output gives 1.24 therms.

$$Oo_{adj} = UEC_{gas\ oven} \bullet EFFgo_{std} = 1.24\ therms \qquad (A.8)$$

The ratio of gas cooktop energy consumption to standard gas oven energy consumption from Eq. A.5 and the baseline efficiency of the gas cooktop from the cost/efficiency table were used to determine the annual useful cooktop cooking energy output of 7.32 therms.

$$ct_{adj} = Rg_{ct\ std} \bullet UEC_{gas\ oven} \bullet EFFg_{ct} = 7.32\ therm \qquad (A.9)$$

Electric Cooking

The calculations for electric cooking were done in a similar manner as gas cooking. The unit energy consumption for electric cooking was the average annual electric cooking energy consumption of 605.1 kWh reported by five utility metering studies[5] done from 1977 to 1988. Metering studies measure cooking energy consumption directly, giving a better measure than conditional demand analysis studies. The average annual cooking energy consumption was assumed to equal the sales weighted average of standard and self-cleaning oven energy consumption and the cooktop energy consumption.

[5] These are the studies listed as SCE '88, Sierra '88, PG&E '85, Potomac '81, and MRI '77 for electricity in Table A.1.

$$
\begin{aligned}
UEC_{elec\ cooking} &= 605.1\ kWh \\
&= MSe_{sc} \bullet UEC_{elec\ oven\ sc} \\
&+ (1 - MSe_{sc}) \bullet UEC_{elec\ oven} \\
&+ UEC_{elec\ cooktop}
\end{aligned}
\tag{A.10}
$$

where,

MSe_{sc} = the market share of electric ovens that are self-cleaning, 55.6% (10),

$UEC_{elec\ oven\ sc}$ = unit energy consumption for self-cleaning electric ovens,

$UEC_{elec\ oven}$ = unit energy consumption for standard electric ovens,

$UEC_{elec\ cooktop}$ = unit energy consumption for electric cooktops.

The average energy consumption of electric self-cleaning ovens was estimated as a fraction of the energy consumption of a standard electric oven plus the self-cleaning energy. The average energy consumption of cooktops was estimated as a fraction of the energy consumption of standard ovens. These fractions were from the ratios of energy consumption in the DOE test procedure. This was done to determine unit energy consumption of self-cleaning ovens and cooktops as a function of the unit energy consumption of the standard electric oven. The formulas for this are:

$$UEC_{elec\ oven\ sc} = Re_{sc\ std} \bullet UEC_{elec\ oven} + Ees \bullet S_e \tag{A.11}$$

and,

$$UEC_{elec\ cooktop} = Re_{ct\ std} * UEC_{elec\ oven} \tag{A.12}$$

where,

$Re_{sc\ std}$ = the ratio of self-cleaning electric oven cooking energy to standard electric cooking energy,

$Re_{ct\ std}$ = the ratio of electric cooktop cooking energy to standard electric oven cooking energy,

Ees = typical self-cleaning energy consumption per cycle for electric self-cleaning ovens, 5.5 kWh,

S_e = number of self-clean cycles per year for electric ovens, 11 from DOE (11)[6].

For the purposes of calculating these ratios, the self-cleaning electric oven cooking energy, the electric cooktop cooking energy, and the standard electric oven cooking energy were calculated as the DOE annual useful cooking energy output divided by the baseline cooking efficiency reported in the cost/efficiency tables (Chapter 1, Sections 1.3.3 and 1.4.3). This assumes the ratio of annual useful cooking energy output for cooktops compared to ovens has not changed significantly.

$$Re_{sc\ std} = \frac{(Oo_{DOE}\ /\ EFFeo_{SC})}{(Oo_{DOE}\ /\ EFFeo_{std})} = .871 \tag{A.13}$$

$$Re_{ct\ std} = \frac{(Oct_{DOE}\ /\ EFFe_{ct})}{(Oo_{DOE}\ /\ EFFeo_{std})} = .924 \tag{A.14}$$

where,

Oo_{DOE} = the annual useful cooking energy output for ovens according to the old DOE test procedure (12), 47.1 kWh,

Oct_{DOE} = the annual useful cooking energy output for cooktops according to the old DOE test procedure (13), 277.7 kWh,

$EFFeo_{SC}$ = the cooking efficiency of the baseline self-cleaning electric oven, from the cost/efficiency table, 13.9%,

$EFFeo_{std}$ = the cooking efficiency of the baseline standard electric oven, from the cost/efficiency table, 12.1%,

$EFFe_{ct}$ = the cooking efficiency of the baseline electric cooktop, from the cost/efficiency table, 77.2%,

At this point, Eq. A.10 for the unit energy consumption for electric cooking can be rewritten so the only unknown variable is the unit energy consumption of a standard electric oven. This is done as

[6] For purposes of calculating a revised value for the annual useful cooking energy output for the proposed DOE test procedure, the number of self-clean cycles was assumed to be 11 for electric ovens. As reported in the Executive Summary of Volume 2 of this TSD, more recent data indicates that the number of self-clean cycles should be 4. But for the years in which the data used in these calculations are based (1977 through 1988), 11 self-clean cycles are assumed to be a more representative value.

follows:

$$EC_{elec\ cooking} = MSe_{sc} \bullet (Re_{sc} \bullet UEC_{elec\ oven} + Ees \bullet S$$
$$+ (1 - MSe_{sc}) \bullet UEC_{elec\ oven}$$
$$+ Re_{ct\ std} \bullet UEC_{elec\ oven} \qquad (A.15)$$

Solving this equation for the unit energy consumption of standard electric ovens yields 293.4 kWh, as shown in the following equation,

$$_{ec\ oven} = \frac{UEC_{elec\ cooking} - Ees \bullet Se}{MSe_{sc} \bullet (Re_{sc\ std} - 1) + Re_{ct\ std} + 1)} = 293. \qquad (A.16)$$

The unit energy consumption of the standard electric oven is the annual useful oven cooking energy output divided by the efficiency of the average standard electric oven. Using the baseline efficiency from the cost/efficiency tables and solving for the annual useful oven cooking energy output (Oo_{adj})gives 35.5 kWh.

$$Oo_{adj} = UEC_{elec\ oven} \bullet EFFeo_{std} = 35.5\ kWh \qquad (A.17)$$

The ratio of electric cooktop energy consumption to standard electric oven energy consumption from Eq. A.5 and the baseline efficiency of the electric cooktop from the cost/efficiency table were used to determine the annual useful cooktop cooking energy output (Oct_{adj}) of 209.4 kWh.

$$ct_{adj} = Re_{ct\ std} \bullet UEC_{elec\ oven} \bullet EFFe_{ct} = 209.4\ kW \qquad (A.18)$$

The annual useful cooktop and oven cooking energy outputs were all converted to kBtu to compare with the original values specified in the DOE test procedure. These values are listed in Table A.3. It is encouraging that annual useful cooking energy outputs for gas and electric products are so close to one another.

Table A.3 Comparison of Annual Useful Cooking Energy Outputs

	DOE (kBtu)	gas (kBtu)	electric (kBtu)
Oven	160.7	124.2	121.2 (35.5 kWh)
Cooktop	947.5	732.5	714.3 (209.4 kWh)

A.1.1 Notes for Table A.1 Annual Electric Cooking Energy Consumption

DOE

This is energy consumption using the unadjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by (Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. The annual energy consumption for an electric coil cooktop was from Table 1.4 Cost-Efficiency Table for Coil Cooktops. The annual energy consumption for a standard electric oven was from Table 1.9 Cost-Efficiency Table for Standard Electric Ovens. The annual energy consumption for a self-cleaning electric oven was from Table 1.10 Cost-Efficiency Table for Self-Cleaning Electric Ovens.

Adjusted

This is energy consumption using the adjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by (Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. The annual energy consumption for an electric coil cooktop was from Table 1.4 Cost-Efficiency Table for Coil Cooktops. The annual energy consumption for a standard electric oven was from Table 1.9 Cost-Efficiency Table for Standard Electric Ovens. The annual energy consumption for a self-cleaning electric oven was from Table 1.10 Cost-Efficiency Table for Self-Cleaning Electric Ovens.

SCE (elec)

Data is metered data from the Residential Energy Usage Comparison project by Southern California Edison Company and EPRI. It is based on a sample of 92 households in Orange County, California. From Smith, B.A., Uhlaner, R.T. and Cason, T.N. "Residential Energy Usage Comparison Project: An Overview", Quantum Consulting Inc., Berkeley, CA, October 1990, prepared for Southern California Edison Company and EPRI, CU-6952, Research Project 2863-3, Table 3-1, Average Annual and Seasonal Energy Usage for Orange County Sample Households, p 3-5.

Sierra, metered (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 4-3, Sierra Pacific Validation Study, p 4-4. This data is from Wright, Roger L. and Curt D. Puckett. "Integrating EIP and HES5 Information for Estimating End-Use Energies. Prepared for Sierra Pacific Power Company, March 1988.

PG&E (AMP)

This study is from end-use metered residential appliances during 1985 and 1986. Brodsky, Joel B. and Susan E. McNicoll;"Residential Appliance Load Study, 1985-1986"; Appliance Metering Project; Regulatory Cost of Service Department; Pacific Gas and Electric Company, September 1987; Table 4-1; "Annual Electricity UEC Estimates", p 4-5.

Potomac

This data was from Applications Engineering & Research, "Domestic Electric Range & Clothes Dryer Usage Study", Potomac Edison Company, July 1981. This is a two-page summary letter.

MRI

Data is from Lawrence, A.G. and Ignelzi, P.C. "Electric Appliance Energy Consumption Survey: Analysis and Revision of the MRI Data", Cambridge Systematic, Inc., Berkeley CA, September 1982, prepared for EPRI, EA-2565, Research Project 576-2, Table 8, "The Marginal Distributions of Energy Use for Electric Appliances Metered by MRI", p 4-3.

AEP (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

BG&E (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

BSG/XENERGY (elec)

"Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New

California Houses, p 8-9.

Sierra (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

TNP (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NMPC

"Demand-Side Management Plan 1988"; Niagara Mohawk Power Corp.; Syracuse, NY, April 1988. As cited in draft RCG/Hagler, Bailly study.

LILCO

Barakat, Howard and Chamberlin, Inc.; "Demand-Side Management Program Analysis"; Long Island Lighting Co.: Berkeley, CA; April 1988. As cited in draft RCG/Hagler, Bailly study.

PSE&G

Public Service Electric & Gas; "1988 Corporate Energy Forecast"; PSE&G; Newark, NJ,; 1988. As cited in draft RCG/Hagler, Bailly study.

CEC (elec)

The 1987 marginal UECs from Forecasting Division, California Energy Commission, "Electricity Report #8, CEC, Sacramento, CA as listed in "Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

CommEd (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

El Paso (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

JCP&L (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

MetEd (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

VEPCO (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A

Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

ACEEE

Geller, H. et al.; "Acid Rain and Electricity Conservation"; American Council for an Energy-Efficient Economy; Wash DC; June 1987. As cited in draft RCG/Hagler, Bailly study.

REEPS

Cambridge Systematics; "REEPS Code: User's Guide"; Electric Power Research Institute; Palo Alto, CA; 1987. As cited in draft RCG/Hagler, Bailly study.

FP&L (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

Gulf (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NPC (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NYSEG (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&Ea (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

RG&E (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19. A footnote in the table indicated this cooking UEC was without microwave.

TVA (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (85)

This data was taken from the same table as the PG&E AMP data. These are preliminary values supplied by the Market Research and Information Section of the Market Planning and Research Department.

SDG&E (85)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

AP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

LP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

MP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

MPC (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NOPS (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of

Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

SDG&E (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

APC (83)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

A.1.2 Notes for Table A.2 Annual Gas Cooking Energy Consumption

DOE

This is energy consumption using the unadjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by(Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. 26.63% of cooktops had standard pilot ignition. The remainder had electronic ignition. 23.74% of ovens were self-cleaning, 28.14% had power cords but were not self-cleaning, and 48.12% were standard ovens with out power cords.

The annual energy consumption of the of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the unadjusted annual useful cooking energy output. The annual energy consumption for the oven was the baseline from Table 1.12 Cost-Efficiency Table for Self-Cleaning Ovens using the unadjusted annual useful cooking energy output.

The energy consumption for the cooktop with standing pilots was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the unadjusted annual useful cooking energy output. The energy consumption for the standard gas oven was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens using the unadjusted annual useful cooking energy output.

Adjusted

This is energy consumption using the adjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by(Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE.

26.63% of cooktops had standard pilot ignition. The remainder had electronic ignition. 23.74% of ovens were self-cleaning, 28.14% had power cords but were not self-cleaning, and 48.12% were standard ovens with out power cords.

The annual energy consumption of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The annual energy consumption for the self-cleaning gas oven was the baseline from Table 1.12 Cost-Efficiency Table for Self-Cleaning Ovens using the adjusted annual useful cooking energy output.

These values are the annual energy consumption for an gas cooktop with electronic ignition and a standard gas oven also . The annual energy consumption of the of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The annual energy consumption for the oven with electronic ignition was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens. This is the annual energy consumption of the baseline minus the difference between electronic ignition and the previous design option.

The energy consumption for the cooktop with standing pilots was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The energy consumption for the oven with standing pilots was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens using the adjusted annual useful cooking energy output.

SCE (gas)

Data is metered data from the Residential Energy Usage Comparison project by Southern California Edison Company and EPRI. It is based on a sample of 92 households in Orange County, California. From Smith, B.A., Uhlaner, R.T. and Cason, T.N. "Residential Energy Usage Comparison Project: An Overview", Quantum Consulting Inc., Berkeley, CA, October 1990, prepared for Southern California Edison Company and EPRI, CU-6952, Research Project 2863-3, Table 3-1, Average Annual and Seasonal Energy Usage for Orange County Sample Households, p 3-5.

BSG/XENERGY (gas)

"Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

CEC (gas)

Are the 1987 marginal UEC's from Forecasting Division, California Energy Commission, "Electricity Report #8, CEC, Sacramento, CA as listed in "Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

SoCal (84 w/o pilots)

Is conditional demand estimates for single family homes in southern California. This data is from Van Lierop, Johannes and Parris, Kenneth M. "Appliance Saturations and Gas Use in the Single-Family Sector", Regulatory Affairs Department, Southern California Gas Company, Los Angeles, CA February, 1988, Table 8. Comparison of Single Family UEC's 20-year Weather, p 4-8. The data for units w/o pilots was for houses built after 1979, when Title-24 went into effect, banning standing pilots in ranges and ovens.

REEPS

Cambridge Systematics; "REEPS Code: User's Guide"; Electric Power Research Institute; Palo Alto, CA; 1987. As cited in draft RCG/Hagler, Bailly study.

SoCal (84 w/pilots)

Is conditional demand estimates for single family homes in southern California. This data is from Van Lierop, Johannes and Parris, Kenneth M. "Appliance Saturations and Gas Use in the Single-Family Sector",Regulatory Affairs Department, Southern California Gas Company, Los Angeles, CA February, 1988, Table 8. Comparison of Single Family UEC's 20-year Weather, p 4-8. This was for houses built before 1979, the year Title-24 went into effect, banning standing pilots in new ranges.

SoCal (81)

Is from Parti, Michael, et al "Residential Appliance Energy Consumption in the Southern California Gas Company Service Territory: A Conditional Energy Demand Analysis",Applied Econometrics, Inc., submitted to Southern California Gas Co., August 1983, p 2.

SoCal (79)

Is from Parti, Michael, et al "Residential Appliance Energy Consumption in the Southern California Gas Company Service Territory: A Conditional Energy Demand Analysis",Applied Econometrics, Inc., submitted to Southern California Gas Co., August 1983, p 2.

A.2 RECENT DATA FOR ANNUAL USEFUL COOKING ENERGY OUTPUT

Background

In the testimony given during public hearings on the NOPR and also in written comments, DOE's estimates for annual energy consumption were criticized as not being current and, as a result, being too high for all cooking products including microwave ovens. The analysis in this section is an attempt to address this criticism. Additionally, the analysis projections within this TSD (i.e., consumer forecasting, life-cycle costs, manufacturer impact, utility impact, and environmental impact) are improved by using the most recent energy usage for a given appliance. These analyses compute projections and forecasts many years into the future. Hence, current energy usage data makes these projections more accurate. This is in comparison to using the annual energy usage values prescribed in the proposed DOE test procedure, which by law are required to be used in the engineering cost-benefit analysis and the determination of design option payback periods, i.e., the effects of various design options on energy consumption must be based on the existing test procedure which includes a prescribed national average energy consumption for each product class. By contrast, the consumer analysis, the life-cycle costs, the manufacturing impact analysis, the utility analysis, and the environmental impact analysis used current, and in effect lower annual energy consumption values than the engineering cost-benefit analysis in Chapter 1 and the payback period analysis in Chapter 4. So as to provide a comparison as to how the various design options analyzed affect cooking product energy use, the engineering cost-benefit analysis in Chapter 1 and the payback period analysis in Chapter 4 were also conducted with the lower annual energy consumption values in addition to those prescribed by the proposed DOE test procedure.

Approach

Several recent studies were analyzed to generate annual energy usage for cooking products. Table A.4 shows a summary of these current annual energy consumption values. Table A.5 shows that this new data consists primarily of recent metered studies, but does include some conditional demand analysis (CDA) estimates. For estimates of electric cooktops and ovens, and also for gas cooktops and ovens, only metered data from 1988 or earlier were included in the estimate. Due to the limited data available for microwave ovens, both CDA and metered study data were included. The trends in cooking usage are clearly headed downward. There is some indication that there are regional and year-to-year effects in cooking usage. No regional effects were included in this analysis. However, it should be noted that in Table A.5 the metered data for the same sample size and location for microwave oven usage increased from 68 to 114 kWh/y in one year (1990 to 1991 respectively; SoCal Edison; sample size of 48). This represents a 40 % increase in microwave oven usage in one year at the same location and with the same metered sample group. There is insufficient data to show whether this is actually a trend or merely an anomaly, i.e., the sample size may be too small to represent the actual usage over a short period of time. Nor should it be concluded that microwave annual usage is increasing in general. It does suggest that a single metered study for annual energy usage may not be representative of the location where the study was done and also may not represent the national average, e.g., written testimony submitted to DOE suggested that the 1988 Sierra data showing 77 kWh/y be used to represent the national average. Clearly more metered studies in more regions of the country over longer periods of time are needed to refine this estimate.

Annual energy consumption was computed for electric ranges, gas ranges, and microwave ovens. For the electric and gas ranges, only metered study data were used to produce the consumption value. The values were sample-weighted, i.e., the sample size was factored into the calculation. For the microwave oven consumption estimate, a different approach was used. Since there were only three metered studies, and two of them showed a 40 % difference within the same study group one year apart, CDA data were also included to help broaden the data base. Table A.5 shows the summary of the consumption analysis.

The average energy consumption values for the electric range and gas range had to be broken down further to yield oven and cooktop annual useful cooking energy outputs. Using the same equations and procedures described in Section A.1, the annual useful cooking energy outputs for electric and gas ovens and cooktops were computed using the most recent annual energy usage data. In accordance with data presented by the Gas Research Institute (14), the computations based on the most recent energy usage data also assumed four self-clean cycles per year for both electric and gas self-cleaning ovens. In addition, the cooking efficiencies of electric and gas ovens and cooktops were updated and set equal to the baseline efficiencies reported in Volume 2, Chapter 1 of this TSD. As shown in Table A.6, a summary of these calculations are reported for not only the most recent annual energy usage data (designated as Method 2), but also for the annual energy usage data that went into developing the annual useful cooking energy output values for the proposed DOE test procedure (designated as Method 1 and detailed in Appendix A.1). Both sets of calculations are presented for comparison purposes.

With regard to microwave ovens, the annual useful cooking energy output proposed by DOE for the microwave oven test procedure was calculated by taking the average annual consumption value of 143.2 kWh/yr (as reported in Table A.5) and multiplying it by an assumed microwave oven baseline efficiency of 54.0% (15). This yields an annual useful cooking energy output of 77.3 kWh/yr which is significantly different than the value of 34.2 kWh/yr reported in the existing DOE test procedure (16). The assumed microwave oven baseline efficiency of 54.0% was derived for the technical analysis that was conducted in support of the minimum efficiency standards proposed by DOE on March 4, 1994 for microwave ovens (17). As reported in Volume 2, Chapter 1 of this TSD, updated data indicates that the baseline efficiency is actually 55.7%. Using a baseline microwave oven efficiency of 55.7% yields an annual useful cooking energy output of 79.8 kWh/yr. This value of 79.8 kWh/yr represents the annual useful cooking energy output based on the most recent field data.

Results

The results of the energy consumption and annual useful cooking energy output analysis are shown below in Table A.4. As a means of further clarification of the annual useful cooking energy output values, Table A.7 has been included. This table shows the difference between annual useful cooking energy output values with regard to the existing DOE test procedure, the proposed DOE test procedure, and the recent energy usage data.

Table A.4 Summary of Annual Energy Consumption and Annual Useful Cooking Energy Output for Cooking Products based on Recent Usage Studies

	Annual Energy Consumption	Annual Useful Cooking Energy Output
GAS		
Range (MMBtu/yr)	6.32	Not Applicable
Oven (kBtu/yr)	Not Available	88.8
Cooktop (kBtu/yr)	Not Available	527.6
ELECTRIC		
Range (kWh/yr)	470.9	Not Applicable
Oven (kWh/yr)	Not Available	29.3
Cooktop (kWh/yr)	Not Available	173.1
Microwave Oven (kWh/yr)	143.2	79.8

Table A.5 Range and Oven Annual Cooking Energy Consumption, Recent Data

Reference[1]	Year of DATA	Type of DATA (Meter/CDA/ or Both)	Sample Size	ELECTRIC (kWh/y) RANGE		ELECTRIC OVEN	ELECTRIC CKTOP	MICROWAVE (kWh/y)		GAS (MMBtu/y) RANGE		GAS OVEN	GAS CKTOP	Comments
1993 TSD "Adjusted" [2]		Both		621.1		327.4	293.7	270		7.47		3.58	3.89	GAS numbers w/pilot; Current numbers in Proposed Test Procedures except for MW ovens
				Data Source Both	Data Source Meter			Data Source Both	Data Source Meter	Data Source Both	Data Source Meter			
1. GRI Report	1994	Meter	92							5.61	5.61	0.076*	0.4831*	w/pilot; Limited data/regional; *Energy "OUTPUT"
											2.24			w/o pilot; Limited data/regional; pilot = 3.37 MMBtu/y
2. AHAM/ADL	1992?	Both		449										Limited data/some included in TSD
3. EPRI (CU-6952)[5]	1990	Meter	92		390					6.81	6.81			SCE Data from '88;same as EPRI CU-7392;
Sierra[5]	1988	Meter	60		484									pilot added
Bonneville[5]	1992	Meter	318		472									
4. LBL-33717	1994	Both		816		386	485	132		5.61				Not all current/some date limited;
Bonneville	1989	Meter	499		482									816 & 5.61 include CDA
Consum Pwr	1988?	Meter	9								5.71			Small sample size
5. EPRI (CU-7392)	1991	Meter	92	385						6.61	6.61			SCE Data from '88;(6.61=3.24+pilot); pilot=3.37=5.61-2.24
6. AEP/RECS	1992	Both		700				191		7.9				Limited data?/national;7.9 from '82 AGA
7. SoCal Edison	1991	Meter	48						114					91 "Res. Appl. End-Use Study Ann. Report"
8. SoCal Edison	1990	Meter	48						68					90 "Res. Appl. End-Use Study Ann. Report"
9. EPRI (CU-6487)	1989	CDA		743				277						Data in TSD
Sierra	1988	Meter	60		484				77					77 kWh/y not included in 277 CDA estimate and not included in TSD
					470.9 [3]						6.32 [3]			See Note 3
AVERAGE								143.2 [4]						See Note 4

References:

1 GRI Report: "Topical Report, Metered Ranges, Cooktops, and Ovens in the Northern Illinois Gas Residential Load Study Data Base", GRI-93/0204, July 1993

2 AHAM/ADL: "Electric Oven and Cooktop Data Analysis", Prepared for AHAM by ADL, Reference 47066, July 15, 1994

3 EPRI (CU-6952), "Residential Energy Usage Comparison Project: An Overview". October, 1990

4 LBL-33717, "Baseline Data for the Residential Sector and Development of a Residential Forecasting Database", May 1994.

5 EPRI (CU-7392), "Residential Energy Usage Comparison: Findings", August 1991.

6 AEP/RECS: AEP Report "Utility Estimates of Household Appliance Electricity Consumption" March 16, 1992, reported in RECS "Household Energy Consumption and Expenditures 1990", DOE/EIA-0321(90), February 1993.

7 & 8 So Cal Edison: "Residential Appliance End-Use Survey" for 1990 and 1991

9 EPRI (CU-6487), "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", October 1989

Notes:

1 Only data from sources dated 1988 to the present were used
2 Current numbers in Proposed test procedure except for MW ovens
3 Based on metered data from '88 or later; Average is sample weighted
4 Based on combination of metered and CDA data from 1988 to the present;Metered data not sample weighted due to small sample size
5 Studies included in AHAM/ADL report (Reference 2)

Table A.6 Range and Oven Annual Useful Cooking Energy Output Calculations[1]

GAS

Annual Energy Use (Therms)

		Method 1[2]	Method 2[3]
Gas Cooking, DATA[4]	=	41.8	29.5
Gas Cooking, CALCULATED	=	39.33	28.10
Gas Oven	=	21.056	15.08
Gas Oven, Self-Cleaning	=	20.68	14.36
Gas Cooktop	=	18.36	13.19

ANNUAL USEFUL COOKING ENERGY OUTPUT

		Method 1[2]	Method 2[3]	
		Therms	*Therms*	*kBtu*
Standard Oven	=	1.242	0.89	89.3
Cooktop	=	7.325	5.26	526.4

Inputs for Calculations / **Definitions**

		Method 1[2]	Method 2[3]	Definitions
MSg(sc)	=	23.74%	23.74%	market share of gas ovens that are self-cleaning
Rg(sc std)	=	0.830	0.830	ratio of self-cleaning gas oven cooking energy to stnd gas oven cooking energy
Rg(ct std)	=	0.872	0.875	ratio of gas cooktop cooking energy to stnd gas oven cooking energy
Egs	=	0.459	0.459	typical self-cleaning energy consumption per cycle
Sg	=	7	4	number of self-clean cycles per year
Oo	=	1.607	1.607	annual useful cooking energy output for gas ovens (old DOE test procedure)
Oct	=	9.475	9.475	annual useful cooking energy output for gas cooktops (old DOE test procedure)
EFFgo(sc)	=	7.1%	7.13%	cooking eff of the baseline self-cleaning gas oven
EFFgo(std)	=	5.9%	5.92%	cooking eff of the baseline standard gas oven
EFFg(ct)	=	39.9%	39.9%	cooking eff of the baseline gas cooktop

ELECTRIC

Annual Energy Use (kWh/yr)

		Method 1[2]	Method 2[3]
Elec Cooking, DATA	=	605.1	470.9
Elec Cooking, CALCULATED	=	578.2	461.1
Elec Oven	=	293.4	236.3
Elec Oven, Self-Cleaning	=	315.9	229.3
Elec Cooktop	=	272.2	228.7

ANNUAL USEFUL COOKING ENERGY OUTPUT

		Method 1[2]	Method 2[3]	
		kWh/yr	*kWh/yr*	*kBtu*
Standard Oven	=	35.5	28.6	97.6
Cooktop	=	209.4	168.6	575.7

Inputs for Calculations / **Definitions**

		Method 1[2]	Method 2[3]	Definitions
MSe(sc)	=	55.6%	55.6%	market share of elec ovens that are self-cleaning
Re(sc std)	=	0.871	0.877	ratio of self-cleaning elec oven cooking energy to stnd elec oven cooking energy
Re(ct std)	=	0.928	0.968	ratio of elec cooktop cooking energy to stnd elec oven cooking energy
Ees	=	5.5	5.5	typical self-cleaning energy consumption per cycle
Se	=	11	4	number of self-clean cycles per year
Oo(DOE)	=	47.1	47.1	annual useful cooking energy output for elec ovens (old DOE test procedure)
Oct(DOE)	=	277.7	277.7	annual useful cooking energy output for elec cooktops (old DOE test procedure)
EFFeo(sc)	=	13.9%	13.79%	cooking eff of the baseline self-cleaning elec oven
EFFeo(std)	=	12.1%	12.1%	cooking eff of the baseline standard elec oven
EFFe(ct)	=	77%	73.7%	cooking eff of the baseline elec cooktop

Notes
(1) All output values calculated in accordance with the procedure shown in Appendix A, section A.1
(2) Method 1: Calculation Method for determining the Annnual Useful Cooking Energy Output for the DOE Proposed Test Procedure; number of self-clean cycles based on Existing DOE test procedure; baseline cooktop and oven cooking efficiencies based on data for DOE's Notice of Proposed Rulemaking (March 4, 1994).
(3) Method 2: Calculation Method for determining the Annnual Useful Cooking Energy Output using more recent field usage data from Table A.5; number of self-clean cycles based on 1994 Gas Research Institute Topical Report (GRI-94/0195); baseline cooktop and oven cooking efficiencies set equal to those values reported in Chapter 1 of this Report.
(4) Data are listed without pilot,e.g 29.5 Therms = 63.2 (usage w/pilot) - 33.7 (pilot)

Table A.7 Summary of Annual Useful Cooking Energy Outputs

	Annual Useful Cooking Energy Output		
	DOE Existing Test Procedure[7]	**DOE Proposed Test Procedure**[8]	**Recent, field usage data**[9]
GAS (kBtu/yr)			
Cooktops	947.5	732.5	527.6
Oven, standard	160.7	124.2	88.8
Oven, self-clean	160.7	124.2	88.8
ELECTRIC (kWh/yr)			
Cooktop, smooth	277.7	209.4	173.1
Cooktop, coil	277.7	209.4	173.1
Oven, standard	47.1	35.5	29.3
Oven, self-clean	47.1	35.5	29.3
Microwave Oven	34.2	77.3	79.8

A.3 MANUFACTURER COST DATA FOR KITCHEN RANGES AND OVENS

The following tables show the total manufacturing costs (1990$) for several design options for nine product classes of kitchen ranges and ovens. The total incremental manufacturing cost is disaggregated into five subcategories: materials (which includes purchased parts), labor, tooling/equipment, shipping/packaging, and indirect. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. There are no indirect costs for microwave ovens. The disaggregated incremental costs for each design option are per unit produced and are not cumulative. The total costs at each design level are cumulative. The estimated uncertainty (at a 95% confidence level) for total incremental costs are provided for each design option. For most of the design options, the estimated uncertainty represents the range of values that were used in determining the incremental cost.

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[7] Existing DOE Test Procedure, 10 CFR, Part 430, Subpart B, Appendix I, April, 1979.

[8] Proposed DOE Test Procedure, FR 60(56) pp 15330-15363, March, 1995.

[9] For electric and gas cooktops and oven, the annual useful cooking energy output values based on "recent, field usage data" in Table A.7 are not exactly equal to those being presented in Table A.6. This is because the values reported in Table A.7 are based on less recent cooktop and oven cooking efficiencies than were used in the calculations for Table A.6. The resulting errors casue minor changes in the life-cycle costs (no greater than 1%) and payback periods (2 to 3%) presented in Volume 2, Chapter 4 of this TSD.

Table A.8 Total Manufacturing Costs for Kitchen Ranges and Ovens (by Design Options)

Electric Cooktop, Coil Element

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1	0	Baseline: Coil Element	41.44	6.91	0.00	0.00	20.72	-	69.06	30%
2,3	1	0 + Imp Contact Conductance	2.28	0.00	0.00	0.00	0.00	2.28	71.34	35%
4,5	2	1 + Reflective Surfaces	0.00	2.60	0.10	0.00	0.34	3.03	74.37	55%

Electric Cooktop, Smooth Element

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline: Solid Disk Element	55.88	8.31	0.00	0.00	24.94	-	89.14	5%
	1	0 + Halogen Lamp Element	99.59	16.60	0.00	0.00	49.80	165.98	255.12	10%
5	2	0 + Induction Element	168.96	28.16	0.00	0.00	84.48	281.60	370.74	50%
	3	0 + Radiant Element	28.89	4.81	0.00	0.00	14.44	48.14	137.28	55%

Gas Cooktop

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline: Conventional	53.45	8.91	0.00	0.00	26.73	-	89.09	10%
1,2	1	0 + Electronic Ignition	12.06	0.00	0.00	0.00	0.00	12.06	101.15	5%
3,4	2	1 + Sealed Burners	20.00	0.00	0.00	0.00	0.00	20.00	121.15	20%
	3	2 + Reflective Surfaces	4.20	0.00	0.45	0.00	1.49	6.14	127.29	55%
5	4	3 + Thermostatic Burner	16.80	0.00	0.05	0.00	0.08	16.93	144.22	20%

Electric Oven, not Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline	87.70	14.62	0.00	0.00	43.85	-	146.17	20%
1	1	0 + Reduced Vent Rate	1.56	0.00	0.05	0.00	0.02	1.63	147.80	90%
2	2	1 + Improved Insulation	2.90	0.20	0.00	0.00	0.11	3.21	151.01	50%
3	3	2 + Improved Door Seals	3.69	0.00	0.00	0.00	0.00	3.69	154.70	25%
4	4	3 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	217.20	50%
	5	4 + Oven Separator	9.00	2.22	0.28	0.08	0.17	11.75	228.95	50%
	6	5 + Forced Convection	39.61	0.00	0.00	0.00	0.00	39.61	268.56	50%
5	7	6 + Reduced Cond. Losses	2.63	0.00	0.56	0.00	0.36	3.55	272.11	55%

Electric Oven, Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3	0	Baseline	111.09	18.52	0.00	0.00	55.55	-	185.15	5%
4	1	0 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	247.65	50%
	2	1 + Oven Separator	9.00	2.22	0.56	0.08	0.34	12.20	259.85	45%
	3	2 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	264.22	55%
5	4	3 + Forced Convection	39.61	0.00	0.00	0.00	0.00	39.61	303.83	50%

Gas Oven, not Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline	91.98	15.36	0.00	0.00	47.46	-	154.80	25%
1,2	1	0 + Electric Glo-bar Ignition	12.06	0.00	0.00	0.00	0.05	12.06	166.86	5%
3	2	1 + Improved Insulation	3.33	0.10	0.00	0.00	0.15	3.58	170.44	45%
	3	2 + Improved Door Seals	1.08	0.00	0.00	0.00	0.00	1.08	171.52	25%
4	4	3 + Forced Convection	18.42	0.93	0.00	0.00	2.79	22.14	193.66	50%
	5	4 + Reduced Vent Rate	1.62	0.00	0.00	0.00	0.00	1.62	195.28	90%
5	6	5 + Oven Separator	20.00	5.78	2.29	0.00	0.20	28.26	223.54	90%
	7	6 + Reduced Cond. Losses	2.63	0.00	0.61	0.00	0.39	3.63	227.17	55%
	8	0 + Electronic Spark Ignition	15.00	0.00	0.00	0.00	0.00	15.00	169.80	5%

Gas Oven, Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline	132.15	22.03	0.00	0.00	66.08	-	220.26	10%
	1	0 + Forced Convection	6.61	1.10	0.00	0.00	3.30	11.01	231.27	50%
	2	1 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	235.64	55%
	3	2 + Improved Door Seals	1.11	0.00	0.00	0.00	0.11	1.22	236.86	25%
5	4	3 + Oven Separator	29.00	7.62	8.90	0.00	0.45	45.97	282.83	90%

Microwave Ovens

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline	-	-	-	-	-	120.00	20%
	1	0 + Eff. Power Source	8.68	0.00	0.00	0.00	8.68	128.68	20%
	2	1 + Eff. Fan	9.27	0.00	0.00	0.00	9.27	137.95	20%
	3	2 + Improved Magnetron	14.58	0.00	0.00	0.00	14.58	152.53	20%
5	4	3 + Reflective Surfaces	18.58	0.00	0.00	0.00	18.58	171.11	20%

REFERENCES

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2. U.S. Office of the Federal Register. 1979. 44 FR 22418, April 13,

3. U.S. Office of the Federal Register. 1995a. *Test Procedures for Water Heaters; Kitchen Ranges, Ovens, and Microwave Ovens; and Clothes Washers; and Reporting Requirements for Clothes Washers, Clothes Dryers and Dishwashers; Proposed Rule.* FR 60(56), March 23, 1995, pp 15330-15363.

4. U.S. Office of the Federal Register. 1995a. *Op. cit.*

5. U.S. Department of Energy. 1993. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Room Air Conditioners, Water Heaters, Direct Heating Equipment, Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts, and Television Sets. Volume 2: Fluorescent Lamp Ballasts, Television Sets, Room Air Conditioners, & Kitchen Ranges and Ovens.* Washington, DC, DOE/EE-0009, Vol. 2 of 3.

6. W. Hamilton. 1990. *Letter to Michael McCabe, DOE*, Association of Home Appliance Manufacturers, March 10, 1990.

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APPENDIX B. LBNL-REM INPUT DATA: COOKTOP, OVEN, AND MICROWAVE OVEN

The following is the regular Lawrence Berkeley National Laboratory-Residential Energy Model (LBNL-REM) input for cooktops, ovens, and microwave ovens. The complete input listing for LBNL-REM is available on electronic medium in ASCII format. The input database includes demographic, economic, and engineering data.

For energy efficiency levels cases, simply replace the input values for two variables in each class of each product regulated. The two variables are labelled: "first year for eff level" and "UEC of eff level." For example, for cooktop efficiency levels taking effect in 1999, change the lines "first year for eff level = 2031" to "first year for eff level = 1999" and enter the appropiate maximum UEC values in the lines "UEC of eff level" for each class.

```
Cooktop
total saturation             = 1.00
elec price multiplier        = 1.04
gas price multiplier         = 1.11
ncalc                        = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs)        = 0
nv5 (# of cap inputs)        = 0
nv2 (# of peq inputs)        = 0
nv4 (# of usage inputs)      = 0
ndis (year to forecast eff)  = 2

---------- UEC of stock unit in base year by fuel type i (MMBTU/yr)
       1       2       3       4       5
  2.6972  3.3728    0.00    0.00    0.00                             ** SF **
  2.6972  3.3728    0.00    0.00    0.00                             ** MF **
  2.6972  3.3728    0.00    0.00    0.00                             ** MH **

---------- Purchase price of a reference unit ($1990) -------------------------
       1       2       3       4       5
  194.18  218.80    0.00    0.00    0.00                             ** SF **
  194.18  218.80    0.00    0.00    0.00                             ** MF **
  194.18  218.80    0.00    0.00    0.00                             ** MH **

---------- Relative UEC and Capacity of a reference unit to a stock unit -------
       1       2       3       4       5
    1.00    1.00    0.00    0.00    0.00                             ** re   **
    1.00    1.00    0.00    0.00    0.00                             ** recap**

---------- Base Year Saturations - c70 ----------------------------------------
       1       2       3       4       5       6
   0.580   0.415   0.000   0.000   0.000   0.005                     ** SF **
   0.450   0.545   0.000   0.000   0.000   0.005                     ** MF **
   0.395   0.595   0.000   0.000   0.000   0.010                     ** MH **

---------- Marginal Saturations for Replacement Units - cn(m=1) ----------------
       1       2       3       4       5       6
   0.610   0.385   0.000   0.000   0.000   0.005                     ** SF **
```

```
   0.490   0.505   0.000   0.000   0.000   0.005                      ** MF **
   0.205   0.790   0.000   0.000   0.000   0.005                      ** MB **

---------- Marginal Saturations for New Houses - cn(m=2) ----------------------
       1       2       3       4       5       6
   0.780   0.210   0.000   0.000   0.000   0.010                      ** SF **
   0.850   0.140   0.000   0.000   0.000   0.010                      ** MF **
   0.410   0.570   0.000   0.000   0.000   0.020                      ** MB **

---------- Historical Shipments (from 1980 to 30 years back) -------------------
 1 Electric
   2.351   2.266   2.361   2.592   2.943   2.872   2.511   2.253   2.327   2.193
   1.997   2.076   2.084   2.018   1.913   1.769   1.650   1.684   1.777   1.622
   1.709   1.893   1.896   1.698   1.645   1.620   1.927   2.050   1.718   1.984
 2 Gas
   2.211   2.132   2.221   2.438   2.768   2.702   2.362   2.119   2.189   2.063
   1.879   1.953   1.961   1.899   1.800   1.665   1.552   1.584   1.672   1.526
   1.608   1.781   1.783   1.598   1.548   1.524   1.813   1.929   1.616   1.867

---------- Retirement Function (from age 1 to 30 years) ------------------------
all i
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .1340   .2140   .2400   .2140   .1340
   .0640   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

---------- Average Life Times (by fuel type i) ---------------------------------
       1       2       3       4       5
    19.0    19.0    19.0     0.0     0.0

---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    .105    0.00    0.00    0.00    0.00                      /* j=1 */
    0.09   -.135    0.00    0.00    0.00    0.00                      /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                      /* j=3 */
    .075    0.00    0.00    0.00    0.00    0.00                      /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                      /* j=5 */
    0.00    0.12    0.00    0.00    0.00   -.585                      /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.18    0.18    0.00    0.00                              /* j=1 */
    0.18    0.15    0.18    0.00    0.00                              /* j=2 */
    0.18    0.18    0.15    0.00    0.00                              /* j=3 */
    0.18    0.18    0.18    0.00    0.00                              /* j=4 */
    0.00    0.00    0.00    0.00    0.00                              /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                              /* j=1 */
    0.00   -0.10    0.00    0.00    0.00                              /* j=2 */
    0.00    0.00   -0.10    0.00    0.00                              /* j=3 */
    0.00    0.00    0.00    0.00    0.00                              /* j=4 */
    0.00    0.00    0.00    0.00    0.00                              /* j=5 */
    0.04    0.04    0.04    0.00    0.00                              /* j=6 */

********************************************************************************
# of products in cooktop     =    2

================================================================================
```

```
product type id#             =   12
product name                 = ECKT (Electric Cooktop)
end-use id#                  =    7
fuel type id#                =    1
number of classes            =    2

---------- the 1st class ---------------------------------------------------
class id#                    =   36
class name                   = Coil (Electric Cooktop, Coil Element)
discount rate                = 0.15
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   271.1
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .737    .737    .737    .737    .737    .737    .737    .737    .737    .737    .737

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                  EF                      Maint
  179.09  234.74                               0.737                       0.00
  183.90  225.21                               0.769                       0.00
  190.79  222.90                               0.777                       0.00

---------- Shipment Distribution (source: none)
      EF   Units
    .737      1.

---------- the 2nd class ---------------------------------------------------
class id#                    =   37
class name                   = Smth (Electric Cooktop, Smooth Element)
discount rate                = 0.15
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   293.7
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .742    .742    .742    .742    .742    .742    .742    .742    .742    .742    .742

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
```

```
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                  Maint
  279.68  233.38                                  0.742                   0.00
  738.77  229.84                                  0.753                   0.00
 1057.24  206.39                                  0.839                   0.00

---------- Shipment Distribution (source: none)
     Kwh   Units
    .742      1.

================================================================================
product type id#            =   13
product name                = GCKT (Gas Cooktop)
end-use id#                 =    7
fuel type id#               =    2
number of classes           =    1

---------- the 1st class ------------------------------------------------------
class id#                   =   38
class name                  = Gas Cooktop
discount rate               = 0.50
last year of historical EF  = 1991
first year for eff level    = 2016
UEC of eff level            =  3.7581
conversion (usage)          =   1.000

---------- Historical energy factors (starting from .85 w/o IID to .083 w/o IID in 1991)
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .193    .212    .230    .249    .267    .286    .305    .323    .342    .360    .379

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu     kWH                             EF                  Maint
  218.80  3.3728    0.00                         0.1564                   0.00
  261.76  1.3230    0.00                         0.3988                   7.25
  299.42  1.2574    0.00                         0.4196                   7.25
  312.67  1.2559    0.00                         0.4201                   7.25
```

```
---------- Shipment Distribution (source: none)
      EF   Units
   .1564   1.0
```

```
Oven
total saturation              = 1.00
elec price multiplier         = 1.04
gas price multiplier          = 1.11
ncalc                         = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs)         = 0
nv5 (# of cap inputs)         = 0
nv2 (# of peq inputs)         = 0
nv4 (# of usage inputs)       = 0
ndis (year to forecast eff)  = 2

---------- UEC of stock unit in base year by fuel type i (MMBTU/yr)
       1       2       3       4       5
  3.3472    2.61    0.00    0.00    0.00                              ** SF **
  3.3472    2.61    0.00    0.00    0.00                              ** MF **
  3.3472    2.61    0.00    0.00    0.00                              ** MB **

---------- Purchase price of a reference unit ($1990) -------------------------
       1       2       3       4       5
  528.48  563.44    0.00    0.00    0.00                              ** SF **
  528.48  563.44    0.00    0.00    0.00                              ** MF **
  528.48  563.44    0.00    0.00    0.00                              ** MB **

---------- Relative UEC and Capacity of a reference unit to a stock unit -------
       1       2       3       4       5
    1.00    1.00    0.00    0.00    0.00                              ** re   **
    1.00    1.00    0.00    0.00    0.00                              ** recap**

---------- Base Year Saturations - c70 ---------------------------------------
       1       2       3       4       5       6
   0.600   0.380   0.000   0.000   0.000   0.020                      ** SF **
   0.460   0.500   0.000   0.000   0.000   0.040                      ** MF **
   0.440   0.520   0.000   0.000   0.000   0.040                      ** MB **

---------- Marginal Saturations for Replacement Units - cn(m=1) ---------------
       1       2       3       4       5       6
   0.540   0.450   0.000   0.000   0.000   0.010                      ** SF **
   0.380   0.600   0.000   0.000   0.000   0.020                      ** MF **
   0.200   0.770   0.000   0.000   0.000   0.030                      ** MB **

---------- Marginal Saturations for New Houses - cn(m=2) ----------------------
       1       2       3       4       5       6
   0.790   0.180   0.000   0.000   0.000   0.030                      ** SF **
   0.840   0.115   0.000   0.000   0.000   0.045                      ** MF **
   0.450   0.500   0.000   0.000   0.000   0.050                      ** MB **

---------- Historical Shipments (from 1980 to 30 years back) ------------------
 1 Electric Ovens
   2.351   2.266   2.361   2.592   2.943   2.872   2.511   2.253   2.327   2.193
   1.997   2.076   2.084   2.018   1.913   1.769   1.650   1.684   1.777   1.622
   1.709   1.893   1.896   1.698   1.645   1.620   1.927   2.050   1.718   1.984
 2 Gas Ovens
   2.211   2.132   2.221   2.438   2.768   2.702   2.362   2.119   2.189   2.063
   1.879   1.953   1.961   1.899   1.800   1.665   1.552   1.584   1.672   1.526
   1.608   1.781   1.783   1.598   1.548   1.524   1.813   1.929   1.616   1.867

---------- Retirement Function (from age 1 to 30 years) -----------------------
all i
```

```
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .1340   .2140   .2400   .2140   .1340
   .0640   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

---------- Average Life Times (by fuel type i) --------------------------------
       1       2       3       4       5
    19.0    19.0     0.0     0.0     0.0

---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    .105    0.00    0.00    0.00    0.00                       /* j=1 */
    0.09   -.135    0.00    0.00    0.00    0.00                       /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=3 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=5 */
    0.00    0.12    0.00    0.00    0.00   -.585                       /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.18    0.00    0.00    0.00                               /* j=1 */
    0.18    0.15    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00   -0.10    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */
    0.04    0.04    0.00    0.00    0.00                               /* j=6 */

********************************************************************************
# of products in oven       =    2

================================================================================
product type id#             =   14
product name                 = EOVN (Electric Oven)
end-use id#                  =    8
fuel type id#                =    1
number of classes            =    2

---------- the 1st class -------------------------------------------------------
class id#                    =   67
class name                   = EnSC (Electric Oven, non-Self-Cleaning)
discount rate                = 0.36
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   966.5
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
```

```
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                   Maint
  399.08  274.94                                 0.1066                   0.000
  402.55  263.23                                 0.1113                   0.000
  410.08  251.78                                 0.1164                   0.000
  427.83  247.96                                 0.1182                   0.000
  577.83  169.57                                 0.1728                   0.000
  607.10  164.60                                 0.1780                   0.000
  704.68  162.70                                 0.1801                   0.000
  713.15  162.42                                 0.1804                   0.000

---------- Shipment Distribution (source: none)
      EF   Units
   .1089      1.

---------- the 2nd class ------------------------------------------------------
class id#                    =   68
class name                   = EwSC (Electric Oven, with-Self-Cleaning)
discount rate                = 0.36
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   398.9
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                   Maint
  630.16  303.72                                 0.0965                   0.000
  817.31  220.02                                 0.1332                   0.000
  854.96  215.54                                 0.1359                   0.000
  867.53  215.27                                 0.1361                   0.000
  989.19  213.73                                 0.1371                   0.000
```

```
---------- Shipment Distribution (source: none)
     Kwh   Units
   .1138      1.

================================================================================
product type id#             =   15
product name                 = GOVN (Gas Oven)
end-use id#                  =    8
fuel type id#                =    2
number of classes            =    2

---------- the 1st class ------------------------------------------------------
class id#                    =   69
class name                   = GnSC (Gas Oven, non-self-cleaning)
discount rate                = 0.43
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   3.728
conversion (usage)           =   1.000 .003412

---------- Historical energy factors  (.15 in 1981 to .766 in 1991 have IID, wt eff
accordingly)
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0341   .0358   .0376   .0393   .0411   .0428   .0446   .0463   .0481   .0498   .0516

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu                                         EF                  Maint
  479.49   2.982    0.00                            0.02978                   0.00
  519.80   1.408   34.16                            0.05826                   0.00
  529.41   1.335   34.16                            0.06117                   0.00
  532.80   1.321   34.16                            0.06177                   0.00
  594.43   1.240   37.08                            0.06497                   0.00
  599.17   1.234   37.08                            0.06527                   0.00
  668.50   1.233   37.08                            0.06534                   0.00

---------- Shipment Distribution (source: none)
      EF   Units
  .02978   1.0

---------- the 2nd class ------------------------------------------------------
class id#                    =   70
class name                   = GwSC (Gas Oven, with-self-cleaning)
discount rate                = 0.43
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   3.728
```

```
conversion (usage)          =   1.000 .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu                                      EF                     Maint
  829.27   1.432   66.68                          0.0535                      0.00
  864.86   1.190   69.70                          0.0622                      0.00
  878.73   1.184   69.70                          0.0624                      0.00
  882.30   1.176   69.70                          0.0628                      0.00
 1032.87   1.120   69.70                          0.0654                      0.00

---------- Shipment Distribution (source: none)
      EF   Units
   .0561      1.
```

```
Mwv Oven
total saturation              = 1.00
elec price multiplier         = 1.04
gas price multiplier          = 1.11
ncalc                         = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs)        = 0
nv5 (# of cap inputs)        = 0
nv2 (# of peq inputs)        = 0
nv4 (# of usage inputs)      = 0
ndis (year to forecast eff)  =10

---------- UEC of stock unit in base year by fuel type i (MMBTU/yr) -----------
       1       2       3       4       5
  1.6468    0.00    0.00    0.00    0.00                              ** SF **
  1.6468    0.00    0.00    0.00    0.00                              ** MF **
  1.6468    0.00    0.00    0.00    0.00                              ** MB **

---------- Purchase price of a reference unit ($1990) -------------------------
       1       2       3       4       5
  189.00    0.00    0.00    0.00    0.00                              ** SF **
  189.00    0.00    0.00    0.00    0.00                              ** MF **
  189.00    0.00    0.00    0.00    0.00                              ** MB **

---------- Relative UEC and Capacity of a reference unit to a stock unit -------
       1       2       3       4       5
    1.00    0.00    0.00    0.00    0.00                              ** re   **
    1.00    0.00    0.00    0.00    0.00                              ** recap**

---------- Base Year Saturations - c70 ---------------------------------------
       1       2       3       4       5       6
   0.190   0.000   0.000   0.000   0.000   0.810                      ** SF **
   0.110   0.000   0.000   0.000   0.000   0.890                      ** MF **
   0.160   0.000   0.000   0.000   0.000   0.840                      ** MB **

---------- Marginal Saturations for Replacement Units - cn(m=1) ----------------
       1       2       3       4       5       6
   0.900   0.000   0.000   0.000   0.000   0.100                      ** SF **
   0.850   0.000   0.000   0.000   0.000   0.150                      ** MF **
   0.900   0.000   0.000   0.000   0.000   0.100                      ** MB **

---------- Marginal Saturations for New Houses - cn(m=2) -----------------------
       1       2       3       4       5       6
   0.770   0.000   0.000   0.000   0.000   0.230                      ** SF **
   0.580   0.000   0.000   0.000   0.000   0.420                      ** MF **
   0.580   0.000   0.000   0.000   0.000   0.420                     ** MB **

---------- Historical Shipments (from 1980 to 30 years back) -------------------
 1 Electric
  3.608   2.807   2.501   2.157   1.749   1.052    .713    .445    .314      0.
      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

---------- Retirement Function (from age 1 to 30 years) ------------------------
all i
   .0000   .0000   .0000   .0000   .0000   .0000   .0320   .1340   .2140   .2400
   .2140   .1340   .0320   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000
```

```
---------- Average Life Times (by fuel type i) --------------------------------
       1       2       3       4       5
    10.0     0.0     0.0     0.0     0.0

---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    0.00    0.00    0.00    0.00    0.00                       /* j=1 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=3 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=5 */
    0.00    0.00    0.00    0.00    0.00   -.585                       /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00    0.00    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00    0.00    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */
    0.04    0.00    0.00    0.00    0.00                               /* j=6 */

********************************************************************************
# of products in Microwave   =    1

================================================================================
product type id#             =   16
product name                 = Micr (Microwave Oven)
end-use id#                  =    9
fuel type id#                =    1
number of classes            =    1

---------- the 1st class -------------------------------------------------------
class id#                    =   71
class name                   = Micr (Microwave Oven)
discount rate                = 0.50
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   966.5
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .557    .557    .557    .557    .557    .557    .557    .557    .557    .557    .557

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0
```

```
---------- Fraction of market share (1981-2015)
l = 1 2 3
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                       Maint
  189.00  143.20                                  0.557                        0.00
  195.88  136.11                                  0.586                        0.00
  208.69  135.58                                  0.588                        0.00
  228.83  133.54                                  0.597                        0.00
  254.50  132.43                                  0.602                        0.00

---------- Shipment Distribution (source: none)
      EF   Units
    .557      1.
```

APPENDIX C. LAWRENCE BERKELEY NATIONAL LABORATORY - MANUFACTURER ANALYSIS MODEL

C.1 INPUT DATA AND DATA DEVELOPMENT

This section presents the Lawrence Berkeley National Laboratory - Manufacturer Analysis Model (LBNL-MAM) input data and sensitivity analysis runs for the analysis of kitchen products.

C.1.1 Engineering Cost Data

The source of the engineering data is the Engineering Analysis described in Chapter 1. The sources of data include manufacturers of these products, discussions with industry consultants, and other studies. The engineering data inputs used in the model consist of several components:

1. The incremental unit variable cost for each of the design options which increase the efficiency of the appliance (e.g., raw materials, direct labor, purchased parts, and increased transportation costs). The incremental variable cost is listed for each design option for each product class.

2. The annual maintenance costs associated with each design option for each product class.

3. The annual unit energy consumption (UEC) associated with each design option for each product class.

4. The installation costs for each design option and product class.

5. Some of the design options also require additional capital investment in the form of retooling, new tooling, or other capital expenditures. These expenses are listed for each design option requiring capital expenditures.

The engineering input data are also listed for each energy efficiency level being analyzed (a base case and the efficiency levels which are the new levels being analyzed). The figures used are exactly the same as those used for the design options, but are calculated for energy efficiency levels instead. The engineering data used as inputs to the LBNL-MAM are listed on the engineering data page of the model, which follows this section. The actual data are listed there rather than here since there are several tables of data.

C.1.2 Industry Market Data

Industry Shipments

These data include annual industry shipments for the base case and the long-run shipments for each of the energy efficiency levels. The base case shipments figure is based on statistics from the Association of Home Appliance Manufacturers.

Price Elasticities and Discount Rates

Price elasticities and consumer discount rates determine the effect on shipments of changes in appliance price and operating cost. The estimated price elasticities for cooktops, ovens, and microwaves were -0.20, -0.44, and -0.49, respectively. The consumer discount rates supplied by the LBNL-REM were 26% for cooktops, 39% for ovens, and 250% for microwave ovens. The source of these elasticities and discount rates is the LBNL-REM. Because these elasticities are important, we perform sensitivity analyses using different elasticities and discount rates.

Product Class Market Share

Each of the product classes has a share of the total market and the market share, or unit sales, for each product class is an input to the model.

Markups

Manufacturers charge different markups over variable cost for different product classes, resulting in different profit margins for different product classes. For cooktops and ovens the estimated markup is 1.37. For microwaves the estimated markup is 1.4. In the absence of any data from the industry, the range of markups for all the products is based on historical data collected from a previous analysis of refrigerators and freezers documented noted in DOE/CE-0277.[1]

Initial Prices

The baseline manufacturer's selling price is used as a base to which are added incremental costs of reaching the higher efficiency levels. The unit price quoted for each product class refers to the most inexpensive, fewest-frills model produced by the manufacturer. The source of the baseline manufacturer's price for each product class is research by LBNL.

---

[1] *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces,* U.S. Department of Energy, DOE/CE-0277, November 1989.

Energy Price

This figure is the ratio of the price of a 1992 kWh to a 1998 kWh. The source is the LBNL-REM. Industry market data appear on the Cost, Sales, and Revenues page of the model.

C.1.3 Financial Input Data

Financial Inputs

The financial inputs for kitchen products are summarized in Tables C.1 to C.4.

Table C.1 Rates of Financial Costs

Variable	Value†	Source
After-tax equity cost of capital‡†	6.8%	MAM calc. from public financial data[2]
Interest rate on debt★‡	2.5%	MAM calc. from public financial data
Interest lost in cash★‡	1.0%	MAM calc. from public financial data
Rate of depreciation	17.7%	Public financial data
Tax rate★★	36%	Tax law

†Rates are assumed to be the same for kitchen products and RACs.
‡Cost of capital and interest rate are *real* rather than nominal.
★Public financial data include data from Value Line, Standard and Poors, Moody's, individual company annual reports, and economic reports.
★★We adopted the 36% discount used by Arthur D. Little and the trade associations in their development of the Government Regulatory Impact Model.

Table C.2 Other Financial Data

Variable	Cooktops	Ovens	Microwaves	Source
Cash	2.50%	2.50%	14.60%	Public financial data
Inventory and receivables	57.50%	57.40%	34.30%	Public financial data
Net depreciable assets	36.60%	36.60%	53.30%	Public financial data
General and administrative expenses	19.00%	19.00%	16.20%	Public financial data
Engineering expense	0.012%	1.20%	1.20%	Public financial data and industry sources[1]

[1]Industry sources include consultants under contract to LBNL and discussions with industry representatives.

Table C.3 Fixed, Variable, and Revenue-Related Cost Split

Variable	Cooktops	Ovens	Microwaves	Source
Fixed part of costs and depr. assets	10%	10%	10%	Industry sources
Fixed part of one-time capital costs	20%	20%	20%	Industry sources
Economic profit	3.89%	3.90%	-3.20%	MAM est. from financial data
Debt/equity ratio	94.20%	94.10%	102.60%	Public financial data
Markup on typical model:	1.37	1.37	1.4	Industry sources
Ratio of highest to lowest markup:	3	3	1	Industry sources

Table C.4 One-Time Costs

Variable	Value†	Source
One-time capital cost's life	8 years	Industry sources
One-time capital cost's tax life	6 years	MAM calculation
Percent additional 1-X capital	50%	MAM estimate
Age of replaced capital	1 years	Public financial data

†Capital characteristics are assumed to be the same for kitchen products and RACs.

The expenditure schedule above lists the costs incurred over time for preparations to meet the new energy efficiency levels. A percentage of the total cost is attributed to each year prior to the efficiency levels' effective date, since that is when these expenses will occur.

C.1.4 LBNL-MAM Inputs and Outputs Showing the Primary Scenario

Tables C.5 to C.40 contain all the data input and outputs used in the analysis of kitchen ranges and ovens. Please see Appendix C of the Methodology volume (Volume 1) for details on the LBNL-MAM.

Table C.5 Cooktops, LBNL-MAM, The Control Panel

		Input		Vari-	Progrm	
COOKTOPS				Level =	1.00	
COOKTOP ANALYSIS		Input		Vari-	Progrm	
CONTROL FACTORS		Value	Cntrl	ation	Value	Name
Price Elasticity		-0.201	0.00	100%	-0.201	IPE
Consumer Discount Rate		25.80%	0.00	100%	0.258	RD
Equity Cost of Capital		0.068	0.00	10%	0.068	ECC
Economic Profit		0.039	0.00	1%	0.039	EP
L-R Fixed Part of Costs & Assets		0.100	0.00	50%	0.100	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	0.00	60%	0.200	F1X
One-Time Capital Costs		0.498	0.00	20%	0.498	CC.N
Unit Variable Cost Increase		$9.13	0.00	30%	9.134	dVC.N
Elasticity Curve Parameter		0.000	0.00	14%	0.000	ro.N
Short Run Price Response to Demand		0.157	0.00	76%	0.157	SRPR

SUMMARY	NAECA BASE	NEW L-RUN	CHANGE	PREVIOUS CHANGE	NEW S-RUN
Shipments	1.43	1.42	-1.16%	-4.98%	1.42
Price	$103.60	$109.30	5.50%	39.65%	$109.25
Revenue (in $M)	148.65	155.01	4.27%	32.70%	154.96
Net Income	7.85	8.24	0.40	1.30	8.45
ROE	10.84%	11.33%	0.49%	-0.42%	11.61%
Operating Cost Elasticity	-0.17				
			Trys =	14	
MIM/GRIM Cost Convergence Factor Status	1				

0 = Only MIM modules are running; 1 = MIM/GRIM cost convergence module running

GRIM NPV RESULTS	Base	NS	Diffs
Millions of dollars @ a 12% discount rate	191.39	197.95	6.55

MIM NPV RESULTS					
Flow of Profit	Base	Eff Levels	NPVg Base	NPVg Stds	DIFFS
12% discount rate	39.23	41.22	327	343	16.60
7% discount rate			560	589	28.45
	39.23	41.00	327	342	14.73
Efficiency Level for New Stds Case	1		Equity (Cal)	349	
Firm equity (New eff level case)	72.79		Equity (base case)	362	
Industry equity (New eff level case)	364				

Table C.6 Cooktops, LBNL-MAM, The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

			Seconds/iteration =		0.42	time
			Iterations to go =		0.00	nn
			Sample Size =		400.00	
Curr. Std. Lev.	1					
	%dQ	%dP	%dR	dNI	dROE.N	dROE.S
Value	-1.16%	5.50%	4.27%	0.40	0.49%	0.77%
Means	-4.63%	41.35%	34.29%	1.62	-0.33%	-1.41%
Stnd. Dev	13.42%	14.00%	19.33%	3.80	2.25%	3.46%
History	-0.01	0.23	0.22	1.58	0.00	-0.01
...	-0.01	0.30	0.29	0.49	-0.01	-0.01
	-0.17	0.68	0.39	1.92	-0.00	-0.08
	-0.05	0.36	0.29	1.45	-0.01	-0.02
	-0.02	0.26	0.23	0.84	-0.01	-0.01
	-0.14	0.39	0.19	-0.20	-0.01	-0.03
	-0.07	0.70	0.57	1.00	-0.02	-0.02
	-0.06	0.37	0.29	0.21	-0.01	-0.02
	-0.07	0.48	0.37	3.31	0.02	-0.01
	-0.03	0.69	0.64	3.29	0.00	-0.01
	-0.03	0.56	0.50	1.29	-0.01	-0.02
	-0.05	0.32	0.26	0.94	-0.00	-0.01
	-0.05	0.58	0.51	5.68	0.03	0.02
	-0.04	0.42	0.37	2.09	0.00	-0.01
	0.02	0.23	0.25	-0.43	-0.02	-0.01
	-0.12	0.34	0.18	-0.18	-0.02	-0.07
	-0.09	0.67	0.52	1.45	-0.01	-0.03
	0.03	0.27	0.31	0.23	-0.02	-0.00
	-0.01	0.37	0.35	1.01	-0.01	-0.01
	-0.02	0.73	0.69	1.31	-0.01	-0.00
	-0.02	0.36	0.33	1.09	-0.00	-0.01
	0.02	0.23	0.26	0.58	-0.01	0.02
	-0.05	0.47	0.39	1.77	-0.00	-0.02
	-0.04	0.29	0.23	0.45	-0.01	-0.06
	-0.03	0.31	0.26	0.60	-0.01	-0.01
	-0.02	0.43	0.40	0.35	-0.02	-0.02
	-0.08	0.47	0.36	2.16	0.01	0.00
	-0.04	0.43	0.37	1.03	-0.01	-0.02
	-0.07	0.38	0.28	0.32	-0.01	-0.03
	-0.02	0.30	0.26	1.17	-0.00	-0.02
	-0.03	0.27	0.23	2.23	0.01	0.00
	0.00	0.27	0.28	-0.34	-0.02	-0.02
	-0.03	0.23	0.20	0.89	-0.00	-0.03

Table C.7 Cooktops, LBNL-MAM, The Accounting Module

(All units are millions or millions of $ unless labeled with $ or %.)

	1987	BASE '96	NEW '96	CHANGE
Revenue	140.33	148.65	155.01	4.3%
Expenses				
Cost of Goods Sold	99.02	106.45	111.71	4.9%
Selling & G & A	17.58	17.77	17.94	1.0%
Engineering	1.11	1.12	1.13	1.0%
Depreciation	9.34	9.34	9.34	NA
1-X Depreciation	0.00	0.06	0.06	NA
Total Expenses	127.05	134.74	140.19	4.0%
Earnings Before Interest & Taxes	13.28	13.91	14.81	6.5%
Interest	1.62	1.65	1.66	0.4%
Earnings Before Taxes	11.66	12.26	13.15	7.3%
Taxes	4.20	4.43	4.76	7.5%
Net Income	7.46	7.83	8.39	7.2%
Gross Margin	29.44%	28.39%	27.93%	-0.5
Return on Sales	5.32%	5.27%	5.41%	0.1
Total Assets	135.56	140.60	141.36	0.5%
Return on Assets (w/intrst taxed)	6.27%	6.32%	6.69%	0.4
Equity	69.80	72.40	72.79	0.5%
Return on Equity	10.69%	10.82%	11.53%	0.7

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.42	1.43	1.42	-1.2%
Price	$98.68	$103.60	$109.30	5.5%
Revenue	140.33	148.65	155.01	4.3%
EXPENSE (W/ INTEREST)				
Fixed Costs	14.03	14.03	14.07	0.3%
Variable Costs (w/ Q)	114.64	122.20	127.61	4.4%
Total Expenses	128.67	136.24	141.68	4.0%
ASSETS				
Cash	3.51	3.54	3.50	-1.2%
Inventories	80.69	81.42	80.47	-1.2%
Depreciable	51.36	55.64	57.39	3.2%
Total Assets	135.56	140.60	141.36	0.5%

Table C.8 Cooktops, LBNL-MAM, The Engineering Inputs Module

		Increment in Additional UVC by Level and Class				
Baseline		0	1	2	3	4
El-Coil		62.8	2.3	2.8	0.0	0.0
El-Smooth		81.7	151.0	256.3	43.8	0.0
Gas		81.1	11.9	20.0	5.2	16.9
New						
VCS.E		Additional UVC. (Above Level 0 cost).				
	CLS	0	1	2	3	4
	0	0	2.28	5.10	0	0
	1	0	151.04	256.26	43.81	0
	2	0	11.93	31.93	37.17	54.03
MC.E		Cumulative Maintenance Costs: Annualized $/Yr				
	CLS	0	1	2	3	4
El-Coil		$0.00	$0.00	$0.00	$0.00	$0.00
El-Smooth		$0.00	$0.00	$0.00	$0.00	$0.00
Gas		$0.00	$7.25	$0.00	$0.00	$0.00
OC.E		Energy Operating Costs: $/Yr				
	CLS	0	1	2	3	4
El-Coil		$19.39	$18.60	$18.41	0	0
El-Smooth		$19.28	$18.99	$17.05	$20.00	0
Gas		$23.44	$9.19	$8.74	$8.73	$8.73
		Total Annual Operating Costs: $/Yr				
	KWS.E	0	1	2	3	4
El-Coil		19.39	18.60	18.41	0.00	0.00
El-Smooth		19.28	18.99	17.05	20.00	0.00
Gas		23.44	16.44	8.74	8.73	8.73
		Incremental Installation Costs				
		0	1	2	3	4
El-Coil		$0.00	$0.00	$0.00	$0.00	$0.00
El-Smooth		$0.00	$0.00	$0.00	$0.00	$0.00
Gas		$0.00	$17.00	$0.00	$0.00	$0.00
		Installation Costs, cumulative above level 0				
INCOST.E		0	1	2	3	4
El-Coil		0	0.00	0.00	0	0
El-Smooth		0	0.00	0.00	0.00	0
Gas		0	17.00	17.00	17.00	17.00

Table C.8 (Continued)

INCREMENTAL PER UNIT, DEPRECIATED INVESTMENT COSTS

	Capital Costs Depreciated Over 7 Years Capital cost / unit / 7	Depreciated Per Unit Incremental Investment Costs			
	0	1	2	3	4
El-Coil	$6.22	$0.00	$0.20	0.00	0.00
El-Smooth	$7.48	$14.94	$25.34	$4.33	0.00
Gas	$8.02	$0.13	$0.00	$0.90	$0.07

CUMULATIVE PER UNIT, DEPRECIATED INVESTMENT COSTS

	Capital Costs Depreciated Over 7 Years Capital cost / unit / 7	Depreciated Per Unit Investment Costs, cumulative above level 0			
	0	1	2	3	4
El-Coil	0.00	0.00	0.20	0.00	0.00
El-Smooth	0.00	14.94	25.34	4.33	0.00
Gas	0.00	0.13	0.13	1.03	1.10

CC.E	Total Cumulative Per Unit Additional CC./7 (Above Level 0 cost.):				
CLS	0	1	2	3	4
0	0.00	0.00	0.20	0.00	0.00
1	0.00	14.94	25.34	4.33	0.00
2	0.00	0.13	0.13	1.03	1.10

ADDITIONAL CC*7 (or life): Per Firm Capital Costs Undepreciated: (Capital cost / unit) * 7

	0	1	2	3	4
El-Coil	0.00	0.00	1.00	0.00	0.00
El-Smooth	0.00	12.81	21.74	3.72	0.00
Gas	0.00	0.54	0.54	4.25	4.55

TOTAL ADDITIONAL CC * 7 MATRIX

ADD.E	0	1	2	3	4
El-Coil	0.00	0.00	1.00	0.00	0.00
El-Smooth	0.00	12.81	21.74	3.72	0.00
Gas	0.00	0.54	0.54	4.25	4.55

	Total Weighted Undepreciated Cumulative Investment Costs				
CCEE.E	0.0	13.4	23.3	8.0	4.6

Total Updepreciated Capital Costs: Per Industry (for GRIM), Tooling Costs Undepreciated, (Capital cost / unit) * 7

	0	1	2	3	4
El-Coil	0.00	0.00	4.98	0.00	0.00
El-Smooth	0.00	64.06	108.68	18.58	0.00
Gas	0.00	2.71	2.71	21.24	22.77

TCC.E: Total Conversion Capital Costs (exc. Design/R&D costs)

	0	1	2	3	4
El-Coil	0.00	0.00	4.98	0.00	0.00
El-Smooth	0.00	64.06	108.68	18.58	0.00
Gas	0.00	2.71	2.71	21.24	22.77

Table C.9 Cooktops, LBNL-MAM, The Standards Level Module

LevIn prev		LEV.B	lev.N	Eng: Levels =	0 ...	9 No. of Eng. Levs.
	-1	0	1	REM: -1='87 0='96	-1 ...	5 No. of Stds Levs.
	1	1	1	1 ==> Stndrds	0 ==> Eng.	
	S|E	S|E.B	S|E.N	Esc = QUIT		

VCS.R Additional UVC by Level and Class. (Above Base cost.)

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	2.275	2.275	5.105	5.105	0	0	0
El-Smooth	0	0	0	0	0	0	256.3	0	0	0
Gas	0	10.96	10.96	10.96	11.93	11.93	37.17	0	0	0

KWS.R Kw Hrs /Yr

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	19.39	19.39	19.39	18.6	18.6	18.41	18.41	0	0	0
El-Smooth	19.28	19.28	19.28	19.28	19.28	19.28	17.05	0	0	0
Gas	23.44	17.01	17.01	17.01	16.44	16.44	8.73	0	0	0

INCOST.R Installation cost by level and class

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	0	0	0	0	0	0	0
El-Smooth	0	0	0	0	0	0	0	0	0	0
Gas	0	15.61	15.61	15.61	17	17	17	0	0	0

CC.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	0	0	0.201	0.201	0	0	0
El-Smooth	0	0	0	0	0	0	25.34	0	0	0
Gas	0	0.121	0.121	0.121	0.131	0.131	1.028	0	0	0

ADD.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	0	0	0.995	0.995	0	0	0
El-Smooth	0	0	0	0	0	0	21.74	0	0	0
Gas	0	0.498	0.498	0.498	0.543	0.543	4.249	0	0	0

CCEE.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
Cumltv CC	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	0.00	0.50	0.50	0.50	0.54	1.54	26.98	0.00	0.00	0.00

	1987	1996	NEW96	1987	1996	NEW96	Cal	Base	New	
	VC87	VCB	VCN	KW87	KWB	KWN	INCST87	INCSTB		INCSTN
El-Coil	0	0.00	0.00	19.39	19.39	19.39	0.00	0.00	0.00	
El-Smooth	0	0.00	0.00	19.28	19.28	19.28	0.00	0.00	0.00	
Gas	0	10.96	10.96	23.44	17.01	17.01	0.00	15.61	15.61	

Table C.9 (Continued)

	1987 CPC87	1996 CPCB	NEW96 CPCN	Weighted Op Cost	Base Case Weighted d P	New Stds Weighted d P	INSTALLATION COST CALCs Cal Wgt INST Cst	Base Wgt Inst. Cst	New Stds Wgt Inst. Cst
El-Coil	0	0.00	0.00	9.67	0.00	0.00	0	0	0
El-Smooth	0	0.00	0.00	1.66	0.00	0.00	0	0	0
Gas	0	0.12	0.12	9.73	4.55	4.55	0	6.48	6.48
			Wgt Fuel Cost: F	21.06	4.55	9.13	0	6.48	6.48
					dVC.B0	dVC.N0	IN.87.0	IN.B.0	IN.N.0

---OUTPUT---

CC.87	CCB	CCN	CC.B0	CC.N0	dVC.B.CV	IN.B	IN.N
0.00	0.50	0.50	0.50	0.50	0.25	6.48	6.48

	Weighted VC: Cal. Case	Weighted VC: Base	Weighted VC: New Stds
El-Coil	0.00	0.00	0.00
El-Smooth	0.00	0.00	0.00
Gas	0.00	4.55	4.55
	0.00	4.55	4.55
	WVC87	WVCB	WVCN

RD.R: Conversion Design/R&D Cost Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	0	0	0	0	0	0	0
El-Smooth	0	0	0	0	0	0	0	0	0	0
Gas	0	0	0	0	0	0	0	0	0	0

TCC.R: Total Capital Costs, exc. R&D Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1	2	3	4	5	6	7	8
El-Coil	0	0	0	0	0	4.977	4.977	0	0	0
El-Smooth	0	0	0	0	0	0	108.7	0	0	0
Gas	0	2.491	2.491	2.491	2.713	2.713	21.24	0	0	0

	Wgt RD: Base	Wgt TCC: Base	Wgt RD: New Stds	Wgt TCC: New Stds
El-Coil	0.00	0.00	0.00	0.00
El-Smooth	0.00	0.00	0.00	0.00
Gas	0.00	2.49	0.00	2.49
	0.00	2.49	0.00	2.49
	RDC.B	TCCC.B	RDC.N	TCCC.N

Table C.10 Cooktops, LBNL-MAM, The Cost, Sales and Revenue Module

COSTS, SALES, and REVENUES							bb	-56
							aa	374
Ratio of highest to lowest markup:					ratio.0	3.00	ratio.cv	0.20
Typical markup over UVC					mid.0	0.38	mid.cv	0.20
Size of firm as % of industry					size.0	0.20		
CALIBRATION CASE (1987)								
	Indst	Relatv	--------- Firm --------					
	Ship.	Ship.	Ship.	Price	Rev.			Weighted
	IQ	Q%	Q.1	P.1/Range	R.1	m.1	UVC.1	UVC
El-Coil	3.55	0.50	0.71	86.10	61.07	1.38	62.39	31.12
El-Smooth	0.61	0.09	0.12	111.87	13.71	1.45	77.21	6.65
Gas	2.95	0.42	0.59	111.07	65.56	1.45	76.77	31.87
TOTAL S	7.11	20.00%	1.42	$99	140.33	1.42	20.00%	69.64
	TS.0	Q.CV	Q.0	P.0	R		P.CV	UVC
BASE CASE (1996)								
	Rule-of-Thb d P	Rule-of-Thb Revenue		Pi.B	Op Cost Ratio	Weightd OpCst-R	Qi.B	Ri.B
El-Coil	0.00	61.62	0	$86.10	1.00	0.50	0.7157	61.62
El-Smooth	0.00	13.83	0	$111.87	1.00	0.09	0.1236	13.83
Gas	15.99	75.68	152	$122.91	0.73	0.30	0.5956	73.20
	0.02	151.13	152	103.6	148.65	-0.11	1.4349	148.65
	Alpha.B	Sum P (2)	Sum (3)	P.B	Sum(Ri)	OC%.B0	Q.B	R.B
NEW EFFICIENCY LEVEL CASE (1996)								
	Rule-of-Thb d P	Rule-of-Thb Revenue		Pi.N	% Chng Op Cost	Weightd OpCst-R	Qi.N	Ri.N
El-Coil	0.00	60.90	0	$86.10	1.00	0.50	0.7073	60.90
El-Smooth	0.00	13.67	0	$111.87	1.00	0.09	0.1222	13.67
Gas	15.99	74.80	151	$136.64	0.73	0.30	0.5887	80.44
TOTAL	-0.04	149.37	151	109.3	155.01	-0.11	1.4182	155.01
	Alpha.N	Sum P (2)	Sum (3)	P.N	Sum(Ri)	OC%.N0	Q.N	R.N

Table C.11 Cooktops, LBNL-MAM, The One-Time Cost Amortization Module

NOTES

Economic life of existing capital	L	8.00	years
Tax life of existing capital	TL	6.00	years
Age of existing capital	AGE	1.00	years
Percent of 1X capital that is add-on (as opposed to replacement capital)	%NC	50%	

COMPUTATIONS

DESCRIPTION		NAME	VALUE	
Continuous After-Tax WACC		ATR	4.19%	
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.070	
exp(-ATR*TL)		EMRT	0.778	
exp(-ATR*L)		EMRL	0.715	
Rate of tax benefit	3.30	BN	0.060	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: (1-%NC)*BN		BEN	0.030	
Discount factor: @exp(-ATR*(L-(TL-RTL)))		DIS	0.75	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.135	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.119	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.318
Savings from not replacing existing Capital later			-0.373	
Loss of Tax Benefit from existing Capital				-0.254
Present Value of CC:			0.627	0.064
Adjusted for Capital Lead Time			0.671	0.069
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.003
LEVELIZED CC FACTOR		CCLF	0.099	0.013
				CCLTF
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.556	
Average Asset Factor for Add-on Capital		AAF	0.278	

INPUT

NEW CAP. COST: 1987-96 ($000)	CC.B0	0.50
1996 CHANGE	CC.N	0.50
COEFFICIENTS OF VARIATION	CCL.CV	0.20
	CC.B.CV	0.25

OUTPUT

	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X CC: Gross	LCC.B	0.05	LCC.N	0.2171
Levelized 1-X CC: Tax Effects	LCC.TB	0.01	LCC.TN	0.03
Levelized 1-X CC: Net	LCC.NB	0.04	LCC.NN	0.19
Levelized 1-X Assets	LA.B	0.14	LA.N	0.61

Table C.12 Cooktops, LBNL-MAM, The Long-Run Model Module

1987 CASE				A.F	A.Q	A:R	A
	Assets -->			0.037	0.929	0.966	136
	Costs except taxes			TC.F	TC.Q	TC:R	TC
	and equity -->			0.100	0.817	0.917	129
				EC.F	EC.Q	EC:R	EC
	Economic costs -->			0.065	0.555	0.981	138
		Economic Income				EI:R	0.0194
		Markup (mu - 1)				mu1	0.1524
		Price Leader's elasticity of demand:					-7.6
BASE 1996				A.BF	A.BQ		A.B
	Assets			5.14	91.72		140.60
				TC.BF	TC.BQ		TC.B
	Costs except taxes			14.03	85.16		136.33
				EC.BF	EC.BQ		EC.B
	Economic costs			9.17	57.85		142.71
	Total Working Capital Correction Assets			WCA.B	3.72		
	Working Capital Correction (Per Unit EC)			WCCEC.B	0.110		
	Total Working Capital Correction (Interest)			WCCI.B	0.093		
NEW 1996				A.NF	A.NQ		A.N
	Assets			5.136	91.717		141.364
				TC.NF	TC.NQ		TC.N
	Costs except taxes			14.069	89.979		141.783
				EC.NF	EC.NQ		EC.N
	Economic costs			9.251	61.238		146.618
	Total Working Capital Correction Assets			WCA.N	7.47		
	Working Capital Correction (Per Unit EC)			WCCEC.N	0.22		
	Total Working Capital Correction (Interest)			WCCI.N	0.19		
	Assets		-----------1987------------		--------BASE 1996---------		---------NEW 1996---------
	Shipments	Q	1.42	Q.B	1.4349	Q.N	1.42
	Price	P	$98.68	P.B	$103.60	P.N	$109.30
	Revenue	R	140.33	R.B	148.65	R.N	155.01
	Unit Var. Cost	UVC	$69.64	UVC.B	$74.18	UVC.N	$78.77
	VCGS	VCGS	99.02	VCGS.B	106.45	VCGS.N	111.71
	1X tax benefit			X1T.B	0.01	X1T.N	0.03
	Pre-tax cost	PTC	128.67	PTC.B	136.38	PTC.N	142.00
	Taxes	TAX	4.20	TAX.B	4.43	TAX.N	4.76
	Net Income	NI	7.46	NI.B	7.85	NI.N	8.24
	Economic Income	EI	2.72	EI.B	2.92	EI.N	3.29
	Equity	EQ	69.80	EQ.B	72.40	EQ.N	72.79
	Retrn on Eqity	ROE	10.69%	ROE.B	10.84%	ROE.N	11.33%
	ACCOUNTING PAGE ONLY CALCULATIONS						
			-----------1987-----------		--------BASE 1996---------		---------NEW 1996---------
	Interest not1X	IC	1.62	IC.B	1.65	IC.N	1.65
	Pre-intrst cst	PIC	127.05	PIC.B	134.74	PIC.N	140.20
	1X deprciation			X1D.B	0.06	X1D.N	0.06
	1X interest			X1I.B	0.00	X1I.N	0.01
	1X equity cost			X1E.B	0.00	X1E.N	0.02

Table C.13 Cooktops, LBNL-MAM, The Short-Run Module

SHORT-RUN ANALYSIS

Short-Run "Supply Elasticity of Price": (Q/P)*dP/dQ			SRQE.0	0.157
Standard Error of SRQE			SRQE.SD	0.120
Random Value selected for this run:			SRQE	0.157

R.S	154.96	P.N	$109.30	
UVC.S	$78.77	Q.N		1.42
VCGS.S	111.72			
TC.S	141.69		ap	bp
TAX.S	4.75	P=a+bQ	92.14	12.07
PTC.S	141.76			
NI.S	8.45			
A.S	141.36			
EQ.S	72.79	P.S	109.25	
ROE.S	11.61%	Q.S	1.42	

Short-Run Assumptions:

The industry installs the long-run optimal level of capital

The industry produces to meet demand at the low short-run price

Table C.14 Cooktops, LBNL-MAM, The Charts Module

Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario= Primary

Control Variables			Possible Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.201	-0.462	0.00%	0.02%	0.03%	-0.01%	-1.05%
RD	0.258	0.593	0.00%	0.08%	0.13%	0.18%	1.19%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	-0.03%
EP	0.039	0.049	0.00%	-0.01%	-0.01%	-0.01%	-0.09%
FCA	0.100	0.160	0.00%	-0.02%	0.00%	0.03%	0.61%
F1X	0.200	0.348	0.00%	0.00%	0.00%	-0.02%	-0.44%
CC.N	0.498	0.607	0.00%	0.00%	0.00%	-0.01%	-0.14%
dVC.N	4.548	6.100	0.06%	0.07%	0.08%	0.09%	0.24%
ro.N	0.000	0.144	0.00%	0.01%	0.01%	-0.01%	-0.42%
SRPR	0.157	0.309	0.00%	0.00%	0.00%	0.00%	0.00%

Table C.15 Cooktops, LBNL-MAM, The Financial Module

DESCRIPTION (FINANCE PAGE)		RANGE NAME	INPUT VALUE	RANGE NAME	C.V.
RATES OF COST					
	After Tax Equity Cost of Capital	ECC.0	6.80%	ECC.CV	10%
	Interest Rate on Debt	I.0	2.50%	I.CV	100.00%
	Interest Lost on Cash	ICash.0	1.00%	ICASH.CV	100.00%
	Rate of Depreciation	Dep.0	17.70%		
	Tax Rate	T.0	36.00%	T.CV	0.00%
ASSETS and COSTS as a PERCENT of REVENUE					
	Cash	C:R.0	2.5%	C:R.CV	100.00%
	Inventory & Receivables	IR:R.0	57.5%	IR:R.CV	27.19%
	Depreciable Assets	DA:R.0	36.6%	DA:R.CV	36.89%
	G & A	G&A.0	19.0%	G&A.CV	40.00%
	Engineering	Eng	1.2%		
FIXED AND VARIABLE COST SPLIT					
	Fixed Part of All Costs & Depr Assets	FCA.0	10.0%	FCA.CV	50%
	Fixed Part of 1-X Capital Cost	F1X.0	20.0%	F1X.CV	60%
OTHER					
	Economic Profit	EP.0	3.9%	EP.CV	1%
	Debt to Equity ratio	DER.0	94.2%	DER.CV	43%
	Markup on typical model	"mid	38.0%		
	Ratio of highest to lowest markup	"ratio	3.00		

OUTPUT		NAME	VALUE		
	Depreciation	DRR	6.7%		
	G&A to Overhead Ratio	G:O	94.1%		
	Engineering to Overhead Ratio	E:O	5.9%		
	Debt Ratio	DR	48.5%		
	Equity Ratio	ER	51.5%		
	Pre-Tax Equity Cost of Capital*	PECC	10.6%		
	Weighted Average Cost of Capital	WACC	6.7%		
	After Tax WACC	ATWACC	4.3%		
	Return on Equity	ROE	10.69%	ROE.0	10.69%

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax exempt.

Table C.16 Cooktops, LBNL-MAM, Cash Flow Analysis

COOKTOPS			Base Year									
COOKTOP ANALYSIS			1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GRIM Switch		0										
Price/Unit			$104	$104	$104	$104	$104	$104	$104	$104	$104	$104
Unit Sales			7.17	7.17	7.17	7.17	7.17	7.17	7.17	7.17	7.17	7.17
Revenues			743	743	743	743	743	743	743	743	743	743
	New	Base										
CGS	84.32	79.77	572	572	572	572	572	572	572	572	572	572
Labor	10.81	10.36	74	74	74	74	74	74	74	74	74	74
Material	56.35	52.84	379	379	379	379	379	379	379	379	379	379
Overhead	13.79	13.21	95	95	95	95	95	95	95	95	95	95
Depreciation	3.37	3.37	24	24	24	24	24	24	24	24	24	24
SG&A			126	126	126	126	126	126	126	126	126	126
R&D			15	15	15	15	15	15	15	15	15	15
Product Conversion			0	0	0	0	0	0	0	0	0	0
Profit Before Tax			45	45	45	45	45	45	45	45	45	45
Taxes (Rate)	36%		16	16	16	16	16	16	16	16	16	16
Net Income before Financing			29	29	29	29	29	29	29	29	29	29
Cash Flow												
Net Income			29	29	29	29	29	29	29	29	29	29
Depreciation			24	24	24	24	24	24	24	24	24	24
Change in Work Capital			0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations			53	53	53	53	53	53	53	53	53	53
Capital Expenditures (Cash used in invest)			(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Conversion Expenditure			0	0	0	0	0	0	0	(1)	(1)	(1)
Cash Used in Investments			(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(31)	(31)
Net Cash Flow			23	23	23	23	23	23	23	22	22	22
				198								

Table C.16 (Continued)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Price/Unit	$109	$109	$109	$109	$109	$109	$109	$109	$109	$109	$109	$109
Unit Sales	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09
Revenues	775	775	775	775	775.04775	775	775	775	775	775	775	775
CGS	599	599	599	599	598.63599	599	599	599	599	599	599	599
Labor	77	77	77	77	77	77	77	77	77	77	77	77
Material	400	400	400	400	400	400	400	400	400	400	400	400
Overhead	98	98	98	98	98	98	98	98	98	98	98	98
Depreciation	24	24	24	24	24	24	24	24	24	24	24	24
SG&A	127	127	127	127	126.99127	127	127	127	127	127	127	127
R&D	16	16	16	16	16	16	16	16	16	16	16	16
Product Conversion	0	0	0	0	0	0	0	0	0	0	0	0
Profit Before Tax	49	49	49	49	49.42449	49	49	49	49	49	49	49
Taxes (Rate)	18	18	18	18	17.79318	18	18	18	18	18	18	18
Net Income before Financing	32	32	32	32	31.63232	32	32	32	32	32	32	32
Cash Flow												
Net Income	32	32	32	32	32	32	32	32	32	32	32	32
Depreciation	24	24	24	24	24	24	24	24	24	24	24	24
Change in Work Capital	5	0	0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations	51	56	56	56	56	56	56	56	56	56	56	56
Capital Expenditures (Cash used in invest)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Conversion Expenditure	0	0	0	0	0	0	0	0	0	0	0	0
Cash Used in Investments	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Net Cash Flow	21	26	26	26	26	26	26	26	26	26	26	26

Table C.17 Ovens, LBNL-MAM, The Control Panel

OVENS					
OVEN ANALYSIS	Input		Vari-	Progrm	
CONTROL FACTORS	Value	Cntrl	ation	Value	Name
Price Elasticity	-0.440	0.00	100%	-0.440	IPE
Consumer Discount Rate	38.90%	0.00	100%	0.389	RD
Equity Cost of Capital	0.068	0.00	10%	0.068	ECC
Economic Profit	0.039	0.00	1%	0.039	EP
L-R Fixed Part of Costs & Assets	0.100	0.00	50%	0.100	FCA
L-R Fixed Part of 1-X Cap. Cost	0.200	0.00	60%	0.200	F1X
One-Time Capital Costs	0.329	0.00	20%	0.329	CC.N
Unit Variable Cost Increase	$4.13	0.00	30%	4.130	dVC.N
Elasticity Curve Parameter	0.000	0.00	14%	0.000	ro.N
Short Run Price Response to Demand	0.157	0.00	76%	0.157	SRPR

	NAECA	NEW		PREVIOUS	NEW
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN
Shipments	1.05	1.05	-0.01%	-19.29%	1.05
Price	$213.17	$214.47	0.61%	60.63%	$214.64
Revenue (in $M)	223.61	224.95	0.60%	29.65%	225.05
Net Income	11.65	11.67	0.02	1.39	11.80
ROE	10.53%	10.51%	-0.02%	-0.77%	10.63%
Operating Cost Elasticity	-0.12				
			Trys =	2208.00	
MIM/GRIM Cost Convergence Factor Status	0				

0 = Only MIM modules are running; 1 = MIM/GRIM cost convergence module running

GRIM NPV RESULTS

	Base	NS	Diffs
Millions of dollars @ a 12% discount rate	287.90	258.06	-29.85

MIM NPV RESULTS

Flow of Profit	Base	Eff Levels	NPVg Base	NPVg Stds	DIFFS
12% discount rate	58.24	58.34	485	486	0.81
7% discount rate			832	833	1.39
	58.24	58.14	485	484	-0.88

Efficiency Level for New Stds Case	2	Equity (Cal)	546
Firm equity (New eff level case)	111.04	Equity (base case)	553
Industry equity (New eff level case)	555		

Table C.18 Ovens, LBNL-MAM, The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

		Secnds/iteration =			0.47	time
		Iterations to go =			0.00	nn
OVENS: ORI DOE TEST		Sample Size =			400.00	

	%dQ	%dP	%dR	dNI	dROE.N	dROE.S
Value	-0.01%	0.61%	0.60%	0.02	-0.02%	0.10%
Means	-20.68%	63.40%	29.03%	1.34	-1.15%	-6.40%
Stnd. Dev	12.06%	20.58%	23.22%	7.91	4.87%	7.04%
History	-0.33	0.61	0.08	-0.99	-0.01	-0.07
...	-0.10	0.34	0.20	-1.23	-0.02	-0.05
	-0.31	0.69	0.17	2.91	0.01	-0.01
	-0.15	0.57	0.33	1.96	-0.01	-0.04
	-0.27	0.84	0.35	-2.21	-0.04	-0.11
	-0.07	0.40	0.30	4.59	0.02	-0.01
	-0.15	0.48	0.26	-3.09	-0.04	-0.08
	-0.32	0.68	0.15	-2.35	-0.03	-0.06
	-0.37	0.57	-0.01	-6.46	-0.06	-0.21
	-0.21	0.42	0.12	-1.63	-0.02	-0.07
	-0.49	0.92	-0.03	-8.47	-0.08	-0.17
	-0.32	0.71	0.16	-3.74	-0.04	-0.16
	-0.26	0.76	0.30	7.17	0.03	-0.08
	-0.02	0.62	0.58	12.83	0.06	0.05
	-0.18	0.56	0.28	0.72	-0.01	-0.04
	-0.16	0.61	0.35	0.22	-0.02	-0.05
	-0.11	0.33	0.19	0.77	-0.01	-0.09
	-0.10	0.58	0.43	2.59	-0.00	-0.04
	-0.26	0.59	0.18	-1.59	-0.02	-0.06
	-0.20	0.33	0.06	-5.92	-0.06	-0.11
	-0.14	0.52	0.30	4.74	0.02	-0.05
	-0.13	1.36	1.05	41.56	0.21	0.06
	-0.14	0.58	0.36	6.14	0.02	-0.06
	-0.18	0.56	0.28	1.95	-0.00	-0.02
	-0.31	0.76	0.21	-2.70	-0.04	-0.09
	-0.06	0.57	0.48	6.98	0.02	-0.01
	-0.29	0.59	0.13	-6.98	-0.07	-0.10
	-0.35	0.75	0.13	-7.13	-0.07	-0.14
	-0.12	1.46	1.16	47.51	0.23	0.18
	-0.06	0.80	0.69	15.93	0.08	0.03
	-0.48	0.70	-0.12	-11.91	-0.11	-0.30
	-0.40	0.44	-0.14	-7.19	-0.06	-0.12
	-0.22	1.17	0.69	11.77	0.03	0.01

Table C.19 Ovens, LBNL-MAM, The Accounting Module

ACCOUNTING SUMMARY — OVEN ANALYSIS: ORI DOE TEST

(All units are millions or millions of $ unless labeled with $ or %.)

	1987	BASE '96	NEW '96	CHANGE
Revenue	219.49	223.61	227.23	1.6%
Expenses				
Cost of Goods Sold	154.86	158.76	161.77	1.9%
Selling & G & A	27.57	27.74	27.81	0.2%
Engineering	1.74	1.75	1.76	0.2%
Depreciation	14.61	14.61	14.61	NA
1-X Depreciation	0.00	0.02	0.04	NA
Total Expenses	198.77	202.89	205.99	1.5%
Earnings Before Interest & Taxes	20.72	20.72	21.24	2.5%
Interest	2.53	2.52	2.52	-0.1%
Earnings Before Taxes	18.20	18.20	18.72	2.9%
Taxes	6.55	6.56	6.75	2.9%
Net Income	11.65	11.64	11.97	2.8%
Gross Margin	29.45%	29.00%	28.81%	-0.2
Return on Sales	5.31%	5.21%	5.27%	0.1
Total Assets	211.87	214.80	214.70	-0.0%
Return on Assets (w/intrst taxed)	6.26%	6.17%	6.33%	0.2
Equity	109.14	110.66	110.60	-0.0%
Return on Equity	10.67%	10.52%	10.83%	0.3

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	1.04	1.05	1.04	-0.8%
Price	$210.42	$213.17	$218.47	2.5%
Revenue	219.49	223.61	227.23	1.6%
EXPENSE (W/ INTEREST)				
Fixed Costs	21.95	21.95	21.98	0.1%
Variable Costs (w/ Q)	179.35	183.39	186.43	1.7%
Total Expenses	201.30	205.34	208.41	1.5%
ASSETS				
Cash	5.56	5.59	5.54	-0.8%
Inventories	125.97	126.68	125.60	-0.8%
Depreciable	80.34	82.53	83.55	1.2%
Total Assets	211.87	214.80	214.70	-0.0%

Table C.20 Ovens, LBNL-MAM, The Engineering Inputs Module

Increment in Additional UVC by Level and Class

Baseline	0	1	2	3	4	5	6	7	8
E-CONV	133.01	1.57	3.18	3.18	56.88	11.42	36.05	2.88	0.00
E-SELF	168.49	56.88	11.54	3.10	36.05	0.00	0.00	0.00	0.00
G-CONV	140.56	11.93	3.44	1.06	19.93	1.62	22.42	3.51	14.84
G-SELF	200.43	10.02	3.10	0.86	36.94	0.00	0.00	0.00	0.00

New

VCS.E — Additional UVC. (Above Level 0 cost). Cumulative costs directly from engineering inputs.

CLS	0	1	2	3	4	5	6	7	8
0	0	$1.6	$4.8	$7.9	$64.8	$76.2	$112.3	$115.2	$0.0
1	0	$56.9	$68.4	$71.5	$107.6	$0.0	$0.0	$0.0	$0.0
2	0	$11.9	$15.4	$16.4	$36.4	$38.0	$60.4	$63.9	$14.8
3	0	$10.0	$13.1	$14.0	$50.9	$0.0	$0.0	$0.0	$0.0

MC.E — CumulativeMaintenance Costs: Annualized $/Yr

CLS	0	1	2	3	4	5	6	7	8
E-CONV	0	0	0	0	0	0	0	0	0
E-SELF	0	0	0	0	0	0	0	0	0
G-CONV	0	0	0	0	0	0	0	0	$7.25
G-SELF	0	0	0	0	0	0	0	0	0

Energy Operating Costs: $/Yr

OC.E	0	1	2	3	4	5	6	7	8
E-CONV	22.71	21.74	20.80	20.48	14.01	13.60	13.44	13.42	$0.00
E-SELF	$25.09	$18.17	$17.80	$17.78	$17.65	$0.00	$0.00	$0.00	$0.00
G-CONV	$20.72	$12.60	$12.10	$12.00	$11.68	$11.64	$11.63	$11.63	$0.00
G-SELF	$15.46	$14.03	$13.99	$13.93	$13.54	$0.00	$0.00	$0.00	$0.00

Operating Costs: $/Yr

KWS.E	0	1	2	3	4	5	6	7	8
E-CONV	$22.71	$21.74	$20.80	$20.48	$14.01	$13.60	$13.44	$13.42	$0.00
E-SELF	$25.09	$18.17	$17.80	$17.78	$17.65	$0.00	$0.00	$0.00	$0.00
G-CONV	$20.72	$12.60	$12.10	$12.00	$11.68	$11.64	$11.63	$11.63	$7.25
G-SELF	$15.46	$14.03	$13.99	$13.93	$13.54	$0.00	$0.00	$0.00	$0.00

Incremental Installation Costs

	0	1	2	3	4	5	6	7	8
E-CONV	0	0	0	0	0	0	0	0	0
E-SELF	0	0	0	0	0	0	0	0	0
G-CONV	$17.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$17.00	0
G-SELF	0	0	0	0	0	0	0	0	0

Table C.20 (Continued)

INCOST.E	Installation Costs, cumulative above level zero 0	1	2	3	4	5	6	7	8
E-CONV	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
E-SELF	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
G-CONV	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$17.0	$0.0
G-SELF	0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0

INCREMENTAL PER UNIT, DEPRECIATED INVESTMENT COSTS

Capital Costs Depreciated Over 7 Years

	Capital cost / unit / 7			Depreciated Per Unit Incremental Investment Costs					
	0	1	2	3	4	5	6	7	8
E-CONV	$10.96	$0.04	$0.03	$4.69	$4.69	$0.27	$2.97	$0.56	$0.00
E-SELF	$13.88	$4.69	$0.55	$1.06	$2.97	$0.00	$0.00	$0.00	$0.00
G-CONV	$11.86	$0.11	$0.04	$0.17	$1.84	$0.04	$1.95	$0.61	$0.14
G-SELF	$16.51	$0.83	$1.06	$0.22	$7.53	$0.00	$0.00	$0.00	$0.00

CUMULATIVE PER UNIT, DEPRECIATED INVESTMENT COSTS

Capital Costs Depreciated Over 5 Years

	Capital cost / unit / 7			Depreciated Per Unit Investment Costs, cumulative above level zero					
	0	1	2	3	4	5	6	7	8
E-CONV	0.00	0.04	0.07	4.76	9.44	9.72	12.69	13.24	0.00
E-SELF	0.00	4.69	5.24	6.29	9.26	0.00	0.00	0.00	0.00
G-CONV	0.00	0.11	0.15	0.31	2.16	2.20	4.16	4.76	0.14
G-SELF	0.00	0.83	1.88	2.10	9.63	0.00	0.00	0.00	0.00

CC.E	Total Cumulative Per Unit Additional CC./7 (Above Level 0 cost.):					Depreciated Per Unit Cumulative Investement Costs, above level zero			
CLS	0	1	2	3	4	5	6	7	8
0	0.00	0.04	0.07	4.76	9.44	9.72	12.69	13.24	0.00
1	0.00	4.69	5.24	6.29	9.26	0.00	0.00	0.00	0.00
2	0.00	0.11	0.15	0.31	2.16	2.20	4.16	4.76	0.14
3	0.00	0.83	1.88	2.10	9.63	0.00	0.00	0.00	0.00

ADDITIONAL CC*7 (or life): Per Firm

Capital Costs Undepreciated

(Capital cost) * 7

	0	1	2	3	4	5	6	7	8
E-CONV	0.00	0.08	0.13	9.01	17.88	18.40	24.03	25.08	0.00
E-SELF	0.00	11.13	12.43	14.94	21.99	0.00	0.00	0.00	0.00
G-CONV	0.00	0.25	0.34	0.73	5.00	5.09	9.61	11.02	0.31
G-SELF	0.00	0.59	1.36	1.51	6.94	0.00	0.00	0.00	0.00

Table C.20 (Continued)

TOTAL ADDITIONAL CC * 7 MATRIX

ADD.E	0	1	2	3	4	5	6	7	8
E-CONV	0.00	0.08	0.13	9.01	17.88	18.40	24.03	25.08	0.00
E-SELF	0.00	11.13	12.43	14.94	21.99	0.00	0.00	0.00	0.00
G-CONV	0.00	0.25	0.34	0.73	5.00	5.09	9.61	11.02	0.31
G-SELF	0.00	0.59	1.36	1.51	6.94	0.00	0.00	0.00	0.00

Total Weighted Undepreciated Cumulative Investment Costs

CCEE.E	0.0	12.1	14.3	26.2	51.8	23.5	33.6	36.1	0.3

Total Undepreciated Capital Costs: Per Industry (for GRIM)

Capital Costs Undepreciated

Capital cost * 7

	0	1	2	3	4	5	6	7	8
E-CONV	0.00	0.29	0.48	32.17	63.86	65.72	85.81	89.57	89.57
E-SELF	0.00	39.73	44.39	53.37	78.55	78.55	78.55	78.55	78.55
G-CONV	0.00	0.90	1.22	2.60	17.84	18.19	34.34	39.35	40.47
G-SELF	0.00	2.12	4.85	5.41	24.77	24.77	24.77	24.77	24.77

TCC.E: Total Conversion Capital Costs (exc. Design/R&D costs)

	0	1	2	3	4	5	6	7	8
E-CONV	0.00	0.29	0.48	32.17	63.86	65.72	85.81	89.57	89.57
E-SELF	0.00	39.73	44.39	53.37	78.55	78.55	78.55	78.55	78.55
G-CONV	0.00	0.90	1.22	2.60	17.84	18.19	34.34	39.35	40.47
G-SELF	0.00	2.12	4.85	5.41	24.77	24.77	24.77	24.77	24.77

Table C.21 Ovens, LBNL-MAM, The Standards Level Module

LevIn prev	LEV.B	lev.N	Eng: Levels =			
-1	0	2	REM: -1='87 0='96		-1 ...	5 No. of Stds Levs.
1	1	1	1 ==> Stndrds	0 ==> Eng.		
S|E	S|E.B	S|E.N	Esc = QUIT			

Eng: Levels = 0 ... 8 No. of Eng. Levs.

VCS.R Additional UVC by Level and Class. (Above Base cost.)

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0.00	0.00	1.57	4.76	7.94	64.81	179.97	0	0	0
E-SELF	0.00	0.00	0.00	0.00	0.00	56.88	107.56	0	0	0
G-CONV	0.00	9.14	9.14	9.14	11.93	16.44	60.41	0	0	0
G-SELF	0.00	0.00	0.00	0.00	0.00	0.00	50.92	0	0	0

KWS.R Kw Hrs /Yr

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	22.71	22.71	21.74	20.8	20.48	14.01	27.43	0	0	0
E-SELF	25.09	25.09	25.09	25.09	25.09	18.17	17.65	0	0	0
G-CONV	20.72	14.498456	14.498456	14.498456	12.6	12	11.63	0	0	0
G-SELF	15.46	15.46	15.46	15.46	15.46	15.46	13.54	0	0	0

INCOST.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0	0	0	0	0	0	0	0	0	0
E-SELF	0	0	0	0	0	0	0	0	0	0
G-CONV	0	0	0	0	0	0	0	0	0	0
G-SELF	0	0	0	0	0	0	0	0	0	0

CC.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0.00	0.00	0.04	0.07	4.76	9.44	22.69	0	0	0
E-SELF	0.00	0.00	0.00	0.00	0.00	4.69	9.26	0	0	0
G-CONV	0.00	0.08	0.08	0.08	0.11	0.31	4.16	0	0	0
G-SELF	0.00	0.00	0.00	0.00	0.00	0.00	9.63	0	0	0

ADD.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0.000	0.000	0.080	0.135	9.008	17.881	42.961	0	0	0
E-SELF	0.000	0.000	0.000	0.000	0.000	11.125	21.995	0	0	0
G-CONV	0.000	0.194	0.194	0.194	0.253	0.728	9.615	0	0	0
G-SELF	0.000	0.000	0.000	0.000	0.000	0.000	6.936	0	0	0

Table C.21 (Continued)

CCEE.R

LEVEL -->	-1=1987	0=1996	1	2	3	4	5	6	7	8
Cumltv CC	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	0.00	0.19	0.27	0.33	9.26	29.73	81.51	0.00	0.00	0.00

	1987	1996	NEW96	1987	1996	NEW96	Cal	Base	New
	VC87	VCB	VCN	KW87	KWB	KWN	INCST87	INCSTB	INCSTN
E-CONV	0	0.00	4.76	22.71	22.71	20.80	0.00	0.00	0.00
E-SELF	0	0.00	0.00	25.09	25.09	25.09	0.00	0.00	0.00
G-CONV	0	9.14	9.14	20.72	14.50	14.50	0.00	0.00	0.00
G-SELF	0	0.00	0.00	15.46	15.46	15.46	0.00	0.00	0.00

					Base Case	New Stds	INSTALLATION COST CALCs		
	1987	1996	NEW96	Weighted	Weighted	Weighted	Cal Wgt	Base	New Stds
	CPC87	CPCB	CPCN	Op Cost	d P	d P	INST Cst	Wgt Inst. Cst	Wgt Inst. Cst
E-CONV	0	0.00	0.07	5.89	0.00	1.23	0.00	0.00	0.00
E-SELF	0	0.00	0.00	8.16	0.00	0.00	0.00	0.00	0.00
G-CONV	0	0.08	0.08	6.57	2.90	2.90	0.00	0.00	0.00
G-SELF	0	0.00	0.00	1.53	0.00	0.00	0.00	0.00	0.00
Wgt Fuel Cost: F				22.14	2.90	7.08	0.00	0.00	0.00
					dVC.B0	dVC.N0	IN.87.0	IN.B.0	IN.N.0

---OUTPUT---

CC.87	CCB	CCN	CC.B0	CC.N0		dVC.B.CV		IN.B	IN.N
0.00	0.19	0.33	0.19	0.33		0.25		0.00	0.00

	Weighted VC: Cal. Case	Weighted VC: Base	Weighted VC: New Stds
E-CONV	0.00	0.00	1.23
E-SELF	0.00	0.00	0.00
G-CONV	0.00	2.90	2.90
G-SELF	0.00	0.00	0.00
	0.00	2.90	4.13
	WVC87	WVCB	WVCN

RD.R: Conversion Design/R&D Cost Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0	0	0	0	0	0	0	0	0	0
E-SELF	0	0	0	0	0	0	0	0	0	0
G-CONV	0	0	0	0	0	0	0	0	0	0
G-SELF	0	0	0	0	0	0	0	0	0	0

Table C.21 (Continued)

TCC.R: Total Capital Costs, exc. R&D Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1	2	3	4	5	6	7	8
E-CONV	0.000	0.000	0.287	0.481	32.172	63.862	153.431	0	0	0
E-SELF	0.000	0.000	0.000	0.000	0.000	39.733	78.553	0	0	0
G-CONV	0.000	0.693	0.693	0.693	0.904	2.601	34.338	0	0	0
G-SELF	0.000	0.000	0.000	0.000	0.000	0.000	24.772	0	0	0

	Wgt RD: Base	Wgt TCC: Base	Wgt RD: New Stds	Wgt TCC: New Stds
E-CONV	0.00	0.00	0.00	0.48
E-SELF	0.00	0.00	0.00	0.00
G-CONV	0.00	0.69	0.00	0.69
G-SELF	0.00	0.00	0.00	0.00
	0.00	0.69	0.00	1.17
	RDC.B	TCCC.B	RDC.N	TCCC.N

Table C.22 Ovens, LBNL-MAM, The Costs, Sales, and Revenue Module

COSTS, SALES, and REVENUES							bb	-137
							aa	841
Ratio of highest to lowest markup:					ratio.0	3.00	ratio.cv	0.20
Typical markup over UVC					mid.0	0.38	mid.cv	0.20
Size of firm as % of industry					size.0	0.20		
CALIBRATION CASE (1987)								
	Indst	Relatv	Firm					
	Ship.	Ship.	Ship.	Price	Rev.			Weighted
	IQ	Q%	Q.1	P.1/Range	R.1	m.1	UVC.1	UVC
E-CONV	1.35	0.26	0.27	182.23	49.30	1.38	132.05	34.25
E-SELF	1.70	0.33	0.34	230.83	78.29	1.44	160.54	52.20
G-CONV	1.65	0.32	0.33	192.56	63.65	1.39	138.31	43.82
G-SELF	0.51	0.10	0.10	274.59	28.25	1.49	184.31	18.18
TOTAL S	5.22	20.00%	1.04	$210	219.49	1.42	20.00%	148.45
	TS.0	Q.CV	Q.0	P.0	R		P.CV	UVC
BASE CASE (1996)								
	Rule-of-Thb d P	Rule-of-Thb Revenue		Pi.B	Op Cost Ratio	Weightd OpCst-R	Qi.B	Ri.B
E-CONV	0.00	49.58	0	$182.23	1.00	0.26	0.2721	49.58
E-SELF	0.00	78.73	0	$230.83	1.00	0.33	0.3411	78.73
G-CONV	12.82	68.27	55	$201.25	0.70	0.22	0.3324	66.89
G-SELF	0.00	28.41	0	$274.59	1.00	0.10	0.1035	28.41
	0.03	224.99	55	213.2	223.61	-0.10	1.0490	223.61
	Alpha.B	Sum P (2)	Sum (3)	P.B	Sum(Ri)	OC%.B0	Q.B	R.B
NEW ENERGY EFFICIENCY CASE (1996)								
	Rule-of-Thb d P	Rule-of-Thb Revenue		Pi.N	% Chng Op Cost	Weightd OpCst-R	Qi.N	Ri.N
E-CONV	6.64	51.38	12	$187.67	0.92	0.24	0.2720	51.05
E-SELF	0.00	78.72	0	$230.83	1.00	0.33	0.3410	78.72
G-CONV	12.82	68.26	55	$200.91	0.70	0.22	0.3323	66.77
G-SELF	0.00	28.41	0	$274.59	1.00	0.10	0.1035	28.41
TOTAL	0.03	226.77	67	214.5	224.95	-0.12	1.0489	224.95
	Alpha.N	Sum P (2)	Sum (3)	P.N	Sum(Ri)	OC%.N0	Q.N	R.N

Table C.23 Ovens, LBNL-MAM, The One-Time Cost Amortization Module

NOTES				
Economic life of existing capital		L	8.00	years
Tax life of existing capital		TL	6.00	years
Age of existing capital		AGE	1.00	years
Percent of 1X capital that is add-on		%NC	50%	
(as opposed to replacement capital)				
COMPUTATIONS				
DESCRIPTION		NAME	VALUE	
Continuous After-Tax WACC		ATR	4.19%	
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.070	
exp(-ATR*TL)		EMRT	0.778	
exp(-ATR*L)		EMRL	0.715	
Rate of tax benefit	3.30	BN	0.060	
Remaining tax life		RTL	5.00	years
Tax Benefit Rate: (1-%NC)*BN		BEN	0.030	
Discount factor: @exp(-ATR*(L-(TL-RTL)))		DIS	0.75	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.135	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.119	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.000	
Tax Benefit of Straight-Line Depreciation				0.318
Savings from not replacing existing Capital later			-0.373	
Loss of Tax Benefit from existing Capital				-0.254
Present Value of CC:			0.627	0.064
Adjusted for Capital Lead Time			0.671	0.069
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.003
LEVELIZED CC FACTOR		CCLF	0.099	0.013
				CCLTF
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.556	
Average Asset Factor for Add-on Capital		AAF	0.278	
INPUT				
NEW CAP. COST: 1987-96 ($000)	CC.B0	0.19		
1996 CHANGE	CC.N	0.33		
COEFFICIENTS OF VARIATION	CCL.CV	0.20		
	CC.B.CV	0.25		
OUTPUT				
	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X CC: Gross	LCC.B	0.02	LCC.N	0.0324
Levelized 1-X CC: Tax Effects	LCC.TB	0.00	LCC.TN	0.00
Levelized 1-X CC: Net	LCC.NB	0.02	LCC.NN	0.03
Levelized 1-X Assets	LA.B	0.05	LA.N	0.09

Table C.24 Ovens, LBNL-MAM, The Long-Run Model Module

1987 CASE			A.F	A.Q	A:R	A
Assets -->			0.037	0.929	0.965	212
Costs except taxes			TC.F	TC.Q	TC:R	TC
and equity -->			0.100	0.817	0.917	201
			EC.F	EC.Q	EC:R	EC
Economic costs -->			0.065	0.555	0.981	215
	Economic Income				EI:R	0.0192
	Markup (mu - 1)				mu1	0.1522
	Price Leader's elasticity of demand:					-7.6
BASE 1996			A.BF	A.BQ		A.B
Assets			8.03	195.40		214.80
			TC.BF	TC.BQ		TC.B
Costs except taxes			21.95	174.83		205.39
			EC.BF	EC.BQ		EC.B
Economic costs			14.33	118.82		217.99
Total Working Capital Correction Assets			WCA.B	1.73		
Working Capital Correction (Per Unit EC)			WCCEC.B	0.070		
Total Working Capital Correction (Interest)			WCCI.B	0.043		
NEW 1996			A.NF	A.NQ		A.N
Assets			8.034	195.404		215.549
			TC.NF	TC.NQ		TC.N
Costs except taxes			21.949	176.062		206.675
			EC.NF	EC.NQ		EC.N
Economic costs			14.336	119.649		218.848
Total Working Capital Correction Assets			WCA.N	2.47		
Working Capital Correction (Per Unit EC)			WCCEC.N	0.10		
Total Working Capital Correction (Interest)			WCCI.N	0.06		
Assets	----------1987----------		---- ---BASE 1996--------		--------NEW 1996--------	
Shipments	Q	1.04	Q.B	1.0490	Q.N	1.05
Price	P	$210.42	P.B	$213.17	P.N	$214.47
Revenue	R	219.49	R.B	223.61	R.N	224.95
Unit Var. Cost	UVC	$148.45	UVC.B	$151.35	UVC.N	$152.58
V. Cost Goods Sold	VCGS	154.86	VCGS.B	158.76	VCGS.N	160.04
1X tax benefit			X1T.B	0.00	X1T.N	0.00
Pre-tax cost	PTC	201.30	PTC.B	205.41	PTC.N	206.71
Taxes	TAX	6.55	TAX.B	6.56	TAX.N	6.57
Net Income	NI	11.65	NI.B	11.65	NI.N	11.67
Economic Income	EI	4.22	EI.B	4.12	EI.N	4.12
Equity	EQ	109.14	EQ.B	110.66	EQ.N	111.04
Retrn on Eqity	ROE	10.67%	ROE.B	10.53%	ROE.N	10.51%
ACCOUNTING PAGE ONLY CALCULATIONS						
	-----------1987-----------		--------BASE 1996---------		---------NEW 1996---------	
Interest not1X	IC	2.53	IC.B	2.52	IC.N	2.53
Pre-intrst cst	PIC	198.77	PIC.B	202.89	PIC.N	204.19
1X deprciation			X1D.B	0.02	X1D.N	0.04
1X interest			X1I.B	0.00	X1I.N	0.00
1X equity cost			X1E.B	0.00	X1E.N	0.00

Table C.25 Ovens, LBNL-MAM, The Short -Run Module

SHORT-RUN ANALYSIS

Short-Run "Supply Elasticity of Price": (Q/P)*dP/dQ				SRQE.0	0.157
Standard Error of SRQE				SRQE.SD	0.120
Random Value selected for this run:				SRQE	0.157
R.S	225.05		P.N	$214.47	
UVC.S	$152.58		Q.N		1.05
VCGS.S	159.98				
TC.S	206.55			ap	bp
TAX.S	6.66		P=a+bQ	180.80	32.28
PTC.S	206.59				
NI.S	11.80				
A.S	215.55				
EQ.S	111.04		P.S	214.64	
ROE.S	10.63%		Q.S	1.05	

Short-Run Assumptions:

The industry installs the long-run optimal level of capital

The industry produces to meet demand at the low short-run price

Table C.26 Ovens, LBNL-MAM, The Charts Module

Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario= Primary

Control Variables			Possible Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.440	-0.440	0.01%	0.00%	-0.04%	-1.38%	-5.69%
RD	0.389	0.894	0.02%	0.03%	0.08%	0.51%	0.84%
ECC	0.068	0.075	0.00%	0.00%	-0.01%	-0.03%	-0.12%
EP	0.039	0.049	0.00%	0.00%	-0.01%	-0.02%	-0.01%
FCA	0.100	0.160	0.00%	0.00%	0.02%	0.45%	1.34%
F1X	0.200	0.348	0.00%	0.00%	-0.13%	-0.36%	-0.75%
CC.N	0.274	0.334	0.00%	0.00%	-0.03%	-0.12%	-0.43%
dVC.N	3.305	4.433	0.03%	0.04%	0.05%	0.17%	0.00%
ro.N	0.000	0.144	0.00%	0.00%	-0.02%	-0.45%	-1.55%
SRPR	0.157	0.309	0	0	0	0	0

Table C.27 Ovens, LBNL-MAM, The Financial Module

Finance Source Inputs

DESCRIPTION (FINANCE PAGE)		RANGE NAME	INPUT VALUE	RANGE NAME	C.V.
RATES OF COST					
	After Tax Equity Cost of Capital	ECC.0	6.80%	ECC.CV	10%
	Interest Rate on Debt	I.0	2.50%	I.CV	100.00%
	Interest Lost on Cash	ICash.0	1.00%	ICASH.CV	100.00%
	Rate of Depreciation	Dep.0	17.70%		
	Tax Rate	T.0	36.00%	T.CV	0.00%
ASSETS and COSTS as a PERCENT of REVENUE					
	Cash	C:R.0	2.5%	C:R.CV	100.00%
	Inventory & Receivables	IR:R.0	57.4%	IR:R.CV	27.19%
	Depreciable Assets	DA:R.0	36.6%	DA:R.CV	36.89%
	G & A	G&A.0	19.0%	G&A.CV	40.00%
	Engineering	Eng	1.2%		
FIXED AND VARIABLE COST SPLIT					
	Fixed Part of All Costs & Depr Assets	FCA.0	10.0%	FCA.CV	50%
	Fixed Part of 1-X Capital Cost	F1X.0	20.0%	F1X.CV	60%
OTHER					
	Economic Profit	EP.0	3.9%	EP.CV	1%
	Debt to Equity ratio	DER.0	94.1%	DER.CV	43%
	Markup on typical model	"mid	38.0%		
	Ratio of highest to lowest markup	"ratio	3.00		

OUTPUT		NAME	VALUE		
	Depreciation	DRR	6.7%		
	G&A to Overhead Ratio	G:O	94.1%		
	Engineering to Overhead Ratio	E:O	5.9%		
	Debt Ratio	DR	48.5%		
	Equity Ratio	ER	51.5%		
	Pre-Tax Equity Cost of Capital*	PECC	10.6%		
	Weighted Average Cost of Capital	WACC	6.7%		
	After Tax WACC	ATWACC	4.3%		
	Return on Equity	ROE	10.67%	ROE.0	10.67%

All interest rates and costs of capital are "real".

*When Pre-Tax ECC is used, all costs are counted tax exempt.

Table C.28 Ovens, LBNL-MAM, Cash Flow Analysis

	New	Base	Base Year 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
OVENS: ORI DOE TEST												
OVEN ANALYSIS: ORI DOE TEST												
GRIM Switch		0										
Price/Unit			$213	$213	$213	$213	$213	$213	$213	$213	$213	$213
Unit Sales			5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25
Revenues			1,118	1,118	1,118	1,118	1,118	1,118	1,118	1,118	1,118	1,118
	New	Base										
CGS	168.27	164.14	861	861	861	861	861	861	861	861	861	861
Labor	21.73	21.32	112	112	112	112	112	112	112	112	112	112
Material	111.91	108.72	570	570	570	570	570	570	570	570	570	570
Overhead	27.71	27.18	143	143	143	143	143	143	143	143	143	143
Depreciation	6.93	6.93	36	36	36	36	36	36	36	36	36	36
SG&A			190	190	190	190	190	190	190	190	190	190
R&D			22	22	22	22	22	22	22	22	22	22
Product Conversion			0	0	0	0	0	0	0	0	0	0
Profit Before Tax			67	67	67	67	67	67	67	67	67	67
Taxes (Rate)		36.00%	24	24	24	24	24	24	24	24	24	24
Net Income Before Financing			43	43	43	43	43	43	43	43	43	43
Cash Flow												
Net Income			43	43	43	43	43	43	43	43	43	43
Depreciation			36	36	36	36	36	36	36	36	36	36
Change in Work Capital			0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations			79	79	79	79	79	79	79	79	79	79
Capital Expenditures (Cash used in invest)			-45	-45	-45	-45	-45	-45	-45	-45	-45	-45
Conversion Expenditure			0	0	0	0	0	0	0	0	0	0
Cash Used in Investments			(45)	(45)	(45)	(45)	(45)	(45)	(45)	(45)	(45)	(45)
Net Cash Flow			35	35	35	35	35	35	35	34	34	34
				292								

Table C.28 (Continued)

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010

Table C.28 (Continued)

Price/Unit	$218	$218	$218	$218	$218	$218	$218	$218	$218	$218	$218	$218
Unit Sales	5	5	5	5	5	5	5	5	5	5	5	5
Revenues	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136	1136
CGS	876	876	876	876	876	876	876	876	876	876	876	876
Labor	113	113	113	113	113	113	113	113	113	113	113	113
Material	582	582	582	582	582	582	582	582	582	582	582	582
Overhead	144	144	144	144	144	144	144	144	144	144	144	144
Depreciation	36	36	36	36	36	36	36	36	36	36	36	36
SG&A	190	190	190	190	190	190	190	190	190	190	190	190
R&D	23	23	23	23	23	23	23	23	23	23	23	23
Product Conversion	0	0	0	0	0	0	0	0	0	0	0	0
Profit Before Tax	70	70	70	70	70	70	70	70	70	70	70	70
Taxes (Rate)	25	25	25	25	25	25	25	25	25	25	25	25
Net Income Before Financing	45	45	45	45	45	45	45	45	45	45	45	45
Cash Flow												
Net Income	45	45	45	45	45	45	45	45	45	45	45	45
Depreciation	36	36	36	36	36	36	36	36	36	36	36	36
Change in Work Capital	3	0	0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations	78	81	81	81	81	81	81	81	81	81	81	81
Capital Expenditures (Cash used in invest)	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45
Conversion Expenditure	0	0	0	0	0	0	0	0	0	0	0	0
Cash Used in Investments	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45	-45
Net Cash Flow	33	36	36	36	36	36	36	36	36	36	36	36

Table C.29 Microwave Ovens, LBNL-MAM, The Control Panel

MICROWAVE OVEN ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity		-0.490	0.00	100%	-0.490	IPE
Consumer Discount Rate		250.00%	0.00	100%	2.500	RD
Equity Cost of Capital		0.068	0.00	10%	0.068	ECC
Economic Profit		-0.032	0.00	1%	-0.032	EP
L-R Fixed Part of Costs & Assets		0.100	0.00	50%	0.100	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	0.00	60%	0.200	F1X
One-Time Capital Costs		0.000	0.00	20%	0.000	CC.N
Unit Variable Cost Increase		$47.43	0.00	30%	47.430	dVC.N
Elasticity Curve Parameter		0.000	0.00	14%	0.000	ro.N
Short Run Price Response to Demand		0.157	0.00	76%	0.157	SRPR
SUMMARY	NAECA BASE	NEW L-RUN	CHANGE	PREVIOUS CHANGE	NEW S-RUN	
Shipments	0.72	0.62	-13.54%	-14.77%	0.63	
Price	$151.20	$203.60	34.66%	39.89%	$199.55	
Revenue (in $M)	109.23	127.16	16.42%	19.22%	125.87	
Net Income	2.01	2.59	0.58	0.75	1.24	
ROE	3.65%	4.81%	1.16%	1.41%	2.30%	

Table C.30 Microwave Ovens, LBNL-MAM, The Monte Carlo Module

MONTE CARLO DETERMINATION OF STANDARD ERRORS OF ESTIMATES.

			Secnds/iteration =		0.41	time
			Iterations to go =		0.00	nn
MICROWAVE OVENS			Sample Size =		400.00	
	%dQ	%dP	%dR	dNI	dROE.N	dROE.S
Value	-13.54%	34.66%	16.42%	0.58	1.16%	-1.35%
Means	-14.09%	36.81%	17.13%	0.81	1.61%	-1.84%
Stnd. Dev	3.68%	11.48%	4.85%	1.24	2.65%	22.20%
History	-0.23	0.67	0.28	2.35	0.04	0.01
...	-0.10	0.25	0.12	0.17	0.00	-0.06
Range	-0.17	0.48	0.22	0.69	0.01	0.01
Name	-0.12	0.30	0.15	1.28	0.02	0.02
Is	-0.08	0.19	0.09	0.57	0.01	0.00
Carlo	-0.12	0.29	0.13	0.30	0.01	0.00
	-0.09	0.21	0.10	-0.06	-0.00	-0.01
	-0.10	0.22	0.11	-0.09	-0.00	-0.00
	-0.11	0.27	0.13	0.36	0.01	0.01
	-0.14	0.37	0.18	2.94	0.06	-0.04
	-0.16	0.44	0.20	-0.12	-0.00	-0.10
	-0.12	0.30	0.15	0.26	0.01	-0.00
	-0.09	0.23	0.12	0.66	0.01	0.01
	-0.13	0.31	0.15	0.49	0.01	-0.02
	-0.18	0.51	0.23	0.55	0.01	-0.10
	-0.15	0.40	0.19	0.40	0.01	0.01
	-0.15	0.39	0.18	0.42	0.01	-0.03
	-0.14	0.35	0.16	-0.22	-0.00	-0.04
	-0.12	0.29	0.14	0.16	0.00	-0.01
	-0.15	0.37	0.17	0.09	0.00	-0.01
	-0.12	0.32	0.16	1.67	0.03	-0.00
	-0.07	0.17	0.08	-0.15	-0.00	-0.01
	-0.13	0.33	0.16	1.39	0.03	-0.03
	-0.11	0.27	0.13	0.23	0.00	-0.01
	-0.18	0.47	0.21	0.01	0.00	-0.03
	-0.18	0.46	0.21	-0.13	-0.00	-0.04
	-0.16	0.43	0.20	0.44	0.01	0.01
	-0.14	0.35	0.16	0.29	0.01	-0.02
	-0.08	0.20	0.10	0.58	0.01	-0.04
	-0.17	0.49	0.23	0.60	0.01	-0.12
	-0.14	0.35	0.17	0.72	0.01	0.01
	-0.16	0.42	0.19	0.02	0.00	-0.04
	-0.11	0.24	0.11	-0.17	-0.00	-0.03
	-0.19	0.53	0.24	2.13	0.04	0.02

Table C.31 Microwave Ovens, LBNL-MAM, The Accounting Module

ACCOUNTING SUMMARY

(All units are millions or millions of $ unless labeled with $ or %.)

	1987	BASE '96	NEW '96	CHANGE
Revenue	109.23	109.23	127.16	16.4%
Expenses				
Cost of Goods Sold	79.15	79.15	98.05	23.9%
Selling & G & A	14.02	14.13	12.45	-11.9%
Engineering	1.04	1.05	0.92	-11.9%
Depreciation	10.59	10.59	10.59	NA
1-X Depreciation	0.00	0.00	0.00	NA
Total Expenses	104.79	104.91	122.01	16.3%
Earnings Before Interest & Taxes	4.43	4.32	5.15	19.3%
Interest	1.29	1.17	1.10	-6.1%
Earnings Before Taxes	3.14	3.14	4.05	28.8%
Taxes	1.13	1.13	1.46	28.8%
Net Income	2.01	2.01	2.59	28.8%
Gross Margin	27.54%	27.54%	22.89%	-4.6
Return on Sales	1.84%	1.84%	2.04%	0.2
Total Assets	111.63	111.63	109.05	-2.3%
Return on Assets (w/intrst taxed)	2.54%	2.47%	3.02%	0.5
Equity	55.10	55.10	53.83	-2.3%
Return on Equity	3.65%	3.65%	4.81%	1.2

ECONOMIC ANALYSIS

	1987	BASE '96	NEW '96	CHANGE
INCOME				
Shipments	0.72	0.72	0.62	-13.5%
Price	$151.20	$151.20	$203.60	34.7%
Revenue	109.23	109.23	127.16	16.4%
EXPENSE (W/ INTEREST)				
Fixed Costs	10.92	10.92	10.92	0.0%
Variable Costs (w/ Q)	95.16	95.16	111.89	17.6%
Total Expenses	106.08	106.08	122.82	15.8%
ASSETS				
Cash	15.95	15.95	13.79	-13.5%
Inventories	37.46	37.46	32.39	-13.5%
Depreciable	58.22	58.22	62.87	8.0%
Total Assets	111.63	111.63	109.05	-2.3%

Table C.32 Microwave Ovens, LBNL-MAM, The Engineering Inputs Module

	Increment in Additional UVC by Level and Class					
Baseline	0	1	2	3	4	5
Microwave ovens	0	5.0	9.3	14.6	18.6	0.0

VCS.E	Additional UVC. (Above Level 0 cost). Cumulative UVC					
CLS	0	1	2	3	4	5
0	0	5	$14.27	$28.85	$47.43	$0.00

MC.E	Cumulative Maintenance Costs: Annualized $/Yr					
CLS	0	1	2	3	4	5
Microwave ovens	0	$0.00	$0.00	$0.00	$0.00	$0.00

	Energy Operating Costs: $/Yr					
OC.E	0	1	2	3	4	5
Microwave ovens	11.83	11.24	11.20	11.03	10.94	$0.00

	Operating Costs: $/Yr					
KWS.E	0	1	2	3	4	5
Microwave ovens	11.83	11.24	11.20	11.03	10.94	0.00

	Installation Costs					
INCOST.E	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

INCREMENTAL PER UNIT, DEPRECIATED INVESTMENT COSTS

	Capital Costs Depreciated Over 5 Years					
	Capital cost / unit / 5		Depreciated Per Unit Inc.l Investment Costs			
	0	1	2	3	4	5
Microwave ovens	0	$0.00	$0.00	$0.00	$0.00	$0.00

	Capital Costs Depreciated Over 5 Years					
	Capital cost / unit / 7		Depreciated Per Unit Inc. Investment Costs			
	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

	Total Cumulative Per Unit					
CC.E	Additional CC./7 (Above Level 0 Cst		Dep. Per Unit Inc Investment Costs			
CLS	0	1	2	3	4	5
0	0	0.00	0.00	0.00	0.00	0.00

ADDITIONAL CC*7 (or life): Per Firm

	Capital Costs Undepreciated					
	(Capital cost / unit) *7					
	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

Table C.32 (Continued)

TOTAL ADDITIONAL CC * 7 MATRIX

ADD.E	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

Total Wgt Undepreciated Cumulative Investment Costs

CCEE.E	0	0.0	0.0	0.0	0.0	0.0

Total Undepreciated Capital Costs: Per Industry (for GRIM)

Capital Costs Undepreciated
(Capital cost / unit) * 7

	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

TCC.E: Total Conversion Capital Costs (exc. Design/R&D costs)

	0	1	2	3	4	5
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00

Table C.33 Microwave Ovens, LBNL-MAM, The Standards Level Module

REM Energy Eff Levels as defined by REM

LevIn prev		LEV.B	lev.N	Eng: Levels = 0...12				
	-1	0	5	REM: -1='87 0='96	1,2,3= NEW			
	1	1	1	1 ==> Stndrds			0 ==> Eng.	
	S|E	S|E.B	S|E.N	Esc = QUIT				

VCS.R	Additional UVC by Level and Class. (Above Base cost.)							
LEVEL -->	-1=1987	0=1996	1.0	2.0	3.0	4.0	5.0	6.0
Microwave ovens	0	0.0	0.0	0.0	0.0	0.0	47.4	0.0
KWS.R	Kw Hrs /Yr							
LEVEL -->	-1=1987	0=1996	$1.00	$2.00	$3.00	$4.00	$5.00	$6.00
Microwave ovens	11.83	12	$11.83	$11.83	$11.83	$11.83	$10.94	$0.00
INCOST.R								
LEVEL -->	-1=1987	0=1996	$1.00	$2.00	$3.00	$4.00	$5.00	$6.00
Microwave ovens	0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
CC.R								
LEVEL -->	-1=1987	0=1996	$1.00	$2.00	$3.00	$4.00	$5.00	$6.00
Microwave ovens	0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
ADD.R								
LEVEL -->	-1=1987	0=1996	1.00	2.00	3.00	4.00	5.00	6.00
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCEE.R								
LEVEL -->	-1=1987	0=1996	1.00	2.00	3.00	4.00	5.00	6.00
Cumltv CC	0	0.00	0.00	0.00	0.00	0.00	0.00	
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1987	1996.00	NEW96	1987.00	1996.00	NEW96	Cal	Base
	VC87	VCB	VCN	KW87	KWB	KWN	INCST87	INCSTB
Microwave ovens	0	0.00	47.43	11.83	11.83	10.94	0.00	0.00
					Base Case	New Stds	INST. COST CALCs	
	1987	$1,996.00	NEW96	Wgt	Wgt	Wgt		Cal Wgt
	CPC87	CPCB	CPCN	Op Cost	d P	d P		INST Cst
Microwave ovens	0	$0.00	$0.00	$11.83	$0.00	$47.43		$0.00
		Wgt Fuel Cost: F		$11.83	$0.00	$47.43		$0.00
					dVC.B0	dVC.N0		IN.87.0

Table C.33 (Continued)

		---OUTPUT---						
	CC.87	CCB	CCN	CC.B0	CC.N0		dVC.B.CV	
	0	$0.00	$0.00	$0.00	$0.00		$0.25	

	Wgt VC: Cal. Case	Wgt CC: Cal. Case		Wgt VC: Base	Wgt CC: Base Case		Wgt VC: New Stds	Wgt CC: New Stds
Microwave ovens	0			$0.00			$47.43	
	0			0			47.43	
	WVC87			WVCB			WVCN	

RD.R: Conversion Design/R&D Cost Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1	2	3	4	5	6
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TCC.R: Total Capital Costs, exc. R&D Per Unit, Cumulative for GRIM

	-1=1987	0=1996	1.00	2.00	3.00	4.00	5.00	6.00
Microwave ovens	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Wgt RD: Base	Wgt TCC: Base		Wgt RD: New Stds	Wgt TCC: New Stds
Microwave ovens	0	0.00		0.00	0.00
	0	0		0	0
	RDC.B	TCCC.B		RDC.N	TCCC.N

Table C.34 Microwave Ovens, LBNL-MAM, The Cost, Sales and Revenue Module

							bb
							aa
Ratio of highest to lowest markup:					ratio.0	1.00	ratio.cv
Typical markup over UVC					mid.0	0.380	mid.cv
Size of firm as % of industry					size.0	0.080	
CALIBRATION CASE (1987)							
	Indst	Relatv	--------- Firm --------				
	Ship.	Ship.	Ship.	Price	Rev.		
	IQ	Q%	Q.1	P.1/Range	R.1	m.1	UVC.1
MW	9.03	1.00	0.722	151.20	109.23	1.38	109.57
TOTALS	9.03	20.00%	0.72	151.20	109.23	1.38	0.20
	TS.0	Q.CV	Q.0	P.0	R		P.CV
BASE CASE (1996)							
	Rule-of-		Rule-of-Thb		Op Cost		Weightd
	Thb d P	Revenue		Pi.B	Ratio	OpCst-R	Qi.B
MW	0.00	109.23	0.00	151.20	1.00	1.00	0.72
	0.00	109.23	0.00	151.20	109.23	0.00	0.72
	Alpha.B	Sum P (2)	Sum (3)	P.B	Sum(Ri)	OC%.B0	Q.B
						check=R.B	
NEW ENERGY EFF CASE (1996)							
	Rule-of-		Rule-of-Thb		% Chng	Weightd	
	Thb d P	Revenue		Pi.N	Op Cost	OpCst-R	Qi.N
MW	65.45	135.31	2675.67	203.60	0.92	0.92	0.62
TOTAL	0.00	135.31	2675.67	203.60	127.16	-0.08	0.62
	Alpha.N	Sum P (2)	Sum (3)	P.N	Sum(Ri)	OC%.N0	Q.N
						check=R.N	

Table C.35 Microwave Ovens, LBNL-MAM, The One-Time Cost Amortization Module

NOTES

Economic life of existing capital	L	8.00	years
Tax life of existing capital	TL	6.00	years
Age of existing capital	AGE	1.00	years
Percent of 1X capital that is add-on	%NC	0.50	
(as opposed to replacement capital)			

COMPUTATIONS

DESCRIPTION		NAME		VALUE
Continuous After-Tax WACC		ATR	0.04	
Weighted CC Lead-Time Factors	0.00	0.28	0.53	0.26
Cumulative CC Lead-Time Factors		LTC.0	1.07	
exp(-ATR*TL)		EMRT	0.78	
exp(-ATR*L)		EMRL	0.72	
Rate of tax benefit	329.68%	BN	0.06	
Remaining tax life		RTL	5.00 years	
Tax Benefit Rate: (1-%NC)*BN		BEN	0.03	
Discount factor: @exp(-ATR*(L-(TL-RTL)))		DIS	0.75	
Loss of tax benefit on portion of existing capital with remaining tax life		LEC1	0.14	
Loss of tax benefit on discounted existing capital expenditure in the future		LEC2	0.12	
LEVELIZED CC			GROSS CC	TAX EFF
Initial Cost			1.00	
Tax Benefit of Straight-Line Depreciation				0.32
Savings from not replacing existing Capital later			-0.38	
Loss of Tax Benefit from existing Capital				-0.26
Present Value of CC:			0.62	0.06
Adjusted for Capital Lead Time			0.67	0.07
Levelized Tax Benefit: 1-X dep. of existing Cap.				0.00
LEVELIZED CC FACTOR		CCLF	0.10	0.01
AVERAGE ASSET FACTOR				
Asset Factor for Any New Cap. or Asset		AFB	0.55	
Average Asset Factor for Add-on Capital		AAF	0.28	

INPUT

NEW CAP. COST: 1987-96 ($000)	CC.B0	0.00
1996 CHANGE	CC.N	0.00
COEFFICIENTS OF VARIATION	CCL.CV	0.20
	CC.B.CV	0.25

OUTPUT

	BASE CASE 1996		NEW STNDS 1996	
Levelized 1-X CC: Gross	LCC.B	0.00	LCC.N	0.00
Levelized 1-X CC: Tax Effects	LCC.TB	0.00	LCC.TN	0.00
Levelized 1-X CC: Net	LCC.NB	0.00	LCC.NN	0.00
Levelized 1-X Assets	LA.B	0.00	LA.N	0.00

Table C.36 Microwave Ovens, LBNL-MAM, The Long-Run Model Module

1987 CASE				A.F	A.Q	A:R	A
	Assets -->			0.053	0.969	1.022	112
	Costs except taxes			TC.F	TC.Q	TC:R	TC
	and equity -->			0.100	0.871	0.971	106
				EC.F	EC.Q	EC:R	EC
	Economic costs -->			0.066	0.590	1.016	111
			Economic Income			EI:R	-0.0159
			Markup (mu - 1)			mu1	0.0846
			Price Leader's elasticity of demand:				-12.8

BASE 1996		A.BF	A.BQ		A.B
	Assets	5.82	146.47		111.63
		TC.BF	TC.BQ		TC.B
	Costs except taxes	10.92	131.73		106.08
		EC.BF	EC.BQ		EC.B
	Economic costs	7.19	89.22		110.96
	Total Working Capital Correction Assets	WCA.B	0.00		
	Working Capital Correction (Per Unit EC)	WCCEC.B	0.000		
	Total Working Capital Correction (Interest)	WCCI.B	0.000		
NEW 1996		A.NF	A.NQ		A.N
	Assets	5.822	146.467		109.051
		TC.NF	TC.NQ		TC.N
	Costs except taxes	10.923	179.160		123.111
		EC.NF	EC.NQ		EC.N
	Economic costs	7.186	120.243		121.605
	Total Working Capital Correction Assets	WCA.N	11.75		
	Working Capital Correction (Per Unit EC)	WCCEC.N	0.66		
	Total Working Capital Correction (Interest)	WCCI.N	0.29		

Assets	-----------1987-----------		------BASE 1996-------		-------NEW 1996-------	
Shipments	Q	0.72	Q.B	0.7224	Q.N	0.62
Price	P	$151.20	P.B	$151.20	P.N	$203.60
Revenue	R	109.23	R.B	109.23	R.N	127.16
Unit Var. Cost	UVC	$109.57	UVC.B	$109.57	UVC.N	$157.00
V. Cost Goods Sold	VCGS	79.15	VCGS.B	79.15	VCGS.N	98.05
1X tax benefit			X1T.B	0.00	X1T.N	0.00
Pre-tax cost	PTC	106.08	PTC.B	106.08	PTC.N	123.11
Taxes	TAX	1.13	TAX.B	1.13	TAX.N	1.46
Net Income	NI	2.01	NI.B	2.01	NI.N	2.59
Economic Income	EI	-1.74	EI.B	-1.74	EI.N	-1.07
Equity	EQ	55.10	EQ.B	55.10	EQ.N	53.83
Return on Equity	ROE	3.65%	ROE.B	3.65%	ROE.N	4.81%

C.37 Microwave Ovens, LBNL-MAM, The Short-Run Module

Short-Run "Supply Elasticity of Price": (Q/P)*dP/dQ			SRQE.0	0.16
Standard Error of SRQE			SRQE.SD	0.120
Random Value selected for this run:			SRQE	0.16
R.S	125.87	P.N	203.60	
UVC.S	157.00	Q.N		0.62
VCGS.S	99.03			
TC.S	123.94		ap	bp
TAX.S	0.70	P=a+bQ	171.64	44.25
PTC.S	123.94			
NI.S	1.24			
A.S	109.05			
EQ.S	$53.83	P.S	199.55	
ROE.S	0.02	Q.S	0.63	

Table C.38 Microwave Ovens, LBNL-MAM, The Charts Module

Sensitivity of ROE to 1 S.E. change in Control Variable

Scenario= Primary

Control Variables			Possible Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.49	-0.55	0.00	0.0%	0.0%	0.00%	0.00%
RD	2.50	5.75	0.00	0.0%	0.0%	0.00%	0.06%
ECC	0.07	0.08	0.00	0.0%	0.0%	0.00%	0.00%
EP	-0.03	-0.02	0.00	0.0%	0.0%	0.00%	0.19%
FCA	0.10	0.16	0.00	0.0%	0.0%	0.00%	1.41%
F1X	0.20	0.35	0.00	0.0%	0.0%	0.00%	0.00%
CC.N	0.00	0.00	0.00	0.0%	0.0%	0.00%	0.00%
dVC.N	0.00	0.00	0.00	0.0%	0.0%	0.00%	0.34%
ro.N	0.00	0.14	0.00	0.0%	0.0%	0.00%	-0.79%
SRPR	0.16	0.59	0.00	0.0%	0.0%	0.00%	0.00%

Table C.39 Microwave Ovens, LBNL-MAM, The Financial Module

DESCRIPTION (FINANCE PAGE)		RANGE NAME	INPUT VALUE	RANGE NAME	C.V.
RATES OF COST					
	After Tax Equity Cost of Capital	ECC.0	0.068	ECC.CV	10.00%
	Interest Rate on Debt	I.0	0.025	I.CV	100.00%
	Interest Lost on Cash	ICash.0	0.01	ICASH.CV	100.00%
	Rate of Depreciation	Dep.0	0.177		
	Tax Rate	T.0	0.36	T.CV	0.00%
ASSETS and COSTS as a PERCENT of REVENUE					
	Cash	C:R.0	14.6%	C:R.CV	100.00%
	Inventory & Receivables	IR:R.0	34.3%	IR:R.CV	27.19%
	Depreciable Assets	DA:R.0	53.3%	DA:R.CV	36.89%
	G & A	G&A.0	16.2%	G&A.CV	40.00%
	Engineering	Eng	1.2%		
FIXED AND VARIABLE COST SPLIT					
	Fixed Part of All Costs & Depr Assets	FCA.0	0.1	FCA.CV	50.00%
	Fixed Part of 1-X Capital Cost	F1X.0	20.0%	F1X.CV	60.00%
OTHER					
	Economic Profit	EP.0	-0.0315	EP.CV	1.00%
	Debt to Equity ratio	DER.0	1.026	DER.CV	43.36%
	Markup on typical model	"mid	$0.38		
	Ratio of highest to lowest markup	"ratio	1		

OUTPUT		NAME	VALUE		
	Depreciation	DRR	0.0969091		
	G&A to Overhead Ratio	G:O	0.9310345		
	Engineering to Overhead Ratio	E:O	0.0689655		
	Debt Ratio	DR	0.5064166		
	Equity Ratio	ER	$0.49		
	Pre-Tax Equity Cost of Capital*	PECC	$0.11		
	Weighted Average Cost of Capital	WACC	$0.07		
	After Tax WACC	ATWACC	$0.04		
	Return on Equity	ROE	$0.04	ROE.0	3.65%

/

Table C.40 Microwave Ovens, LBNL-MAM Cash Flow Analysis

			Base Year 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
GRIM Switch	0											
Price/Unit			$151	$151	$151	$151	$151	$151	$151	$151	$151	$151
Unit Sales			3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61
Revenues			546	546	546	546	546	546	546	546	546	546
	New	Base										
CGS	163.85	116.42	421	421	421	421	421	421	421	421	421	421
Labor	19.86	15.12	55	55	55	55	55	55	55	55	55	55
Material	113.75	77.11	279	279	279	279	279	279	279	279	279	279
Overhead	25.33	19.28	70	70	70	70	70	70	70	70	70	70
Depreciation	4.91	4.91	18	18	18	18	18	18	18	18	18	18
SG&A			93	93	93	93	93	93	93	93	93	93
R&D			11	11	11	11	11	11	11	11	11	11
Product Conv.			0	0	0	0	0	0	0	0	0	0
Profit Before Tax			33	33	33	33	33	33	33	33	33	33
Taxes (Rate)	36%		12	12	12	12	12	12	12	12	12	12
Net Income Before Financing			21	21	21	21	21	21	21	21	21	21
Cash Flow												
Net Income			21	21	21	21	21	21	21	21	21	21
Depreciation			18	18	18	18	18	18	18	18	18	18
Change in Work Capital			0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations			39	39	39	39	39	39	39	39	39	39
Capital Expenditures			(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)
(Cash used in invest)												
Conversion Expenditure			0	0	0	0	0	0	0	0	0	0
Cash Used in Investments			(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)
Net Cash Flow			17	17	17	17	17	17	17	17	17	17
				120								

Table C.40 (Continued)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Price/Unit	$204	$204	$204	$204	$204	$204	$204	$204	$204	$204	$204	$204
Unit Sales	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
Revenues	636	636	636	636	636	636	636	636	636	636	636	636
CGS	516	516	516	516	516	516	516	516	516	516	516	516
Labor	62	62	62	62	62	62	62	62	62	62	62	62
Material	355	355	355	355	355	355	355	355	355	355	355	355
Overhead	81	81	81	81	81	81	81	81	81	81	81	81
Depreciation	18	18	18	18	18	18	18	18	18	18	18	18
SG&A	95	95	95	95	95	95	95	95	95	95	95	95
R&D	13	13	13	13	13	13	13	13	13	13	13	13
Product Conv.	0	0	0	0	0	0	0	0	0	0	0	0
Profit Before Tax	25	25	25	25	25	25	25	25	25	25	25	25
Taxes	9	9	9	9	9	9	9	9	9	9	9	9
Net Income Before Financing	16	16	16	16	16	16	16	16	16	16	16	16
Cash Flow												
Net Income	16	16	16	16	16	16	16	16	16	16	16	16
Depreciation	18	18	18	18	18	18	18	18	18	18	18	18
Change in Work Capital	15	0	0	0	0	0	0	0	0	0	0	0
Cash Flows from Operations	18	34	34	34	34	34	34	34	34	34	34	34
Capital Expenditures	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)
(Cash used in invest)												
Conversion Expenditure	0	0	0	0	0	0	0	0	0	0	0	0
Cash Used in Investments	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)
Net Cash Flow	(3)	12	12	12	12	12	12	12	12	12	12	12

```
   0.780   0.210   0.000   0.000   0.000   0.010                     ** SF **
   0.850   0.140   0.000   0.000   0.000   0.010                     ** MF **
   0.410   0.570   0.000   0.000   0.000   0.020                     ** MB **

---------- Historical Shipments (from 1980 to 30 years back) -------------------
 1 Electric
   2.351   2.266   2.361   2.592   2.943   2.872   2.511   2.253   2.327   2.193
   1.997   2.076   2.084   2.018   1.913   1.769   1.650   1.684   1.777   1.622
   1.709   1.893   1.896   1.698   1.645   1.620   1.927   2.050   1.718   1.984
 2 Gas
   2.211   2.132   2.221   2.438   2.768   2.702   2.362   2.119   2.189   2.063
   1.879   1.953   1.961   1.899   1.800   1.665   1.552   1.584   1.672   1.526
   1.608   1.781   1.783   1.598   1.548   1.524   1.813   1.929   1.616   1.867

---------- Retirement Function (from age 1 to 30 years) -----------------------
all i
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .1340   .2140   .2400   .2140   .1340
   .0640   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

---------- Average Life Times (by fuel type i) --------------------------------
       1       2       3       4       5
    19.0    19.0    19.0     0.0     0.0

---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    .105    0.00    0.00    0.00    0.00                      /* j=1 */
    0.09   -.135    0.00    0.00    0.00    0.00                      /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                      /* j=3 */
    .075    0.00    0.00    0.00    0.00    0.00                      /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                      /* j=5 */
    0.00    0.12    0.00    0.00    0.00   -.585                      /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.18    0.18    0.00    0.00                              /* j=1 */
    0.18    0.15    0.18    0.00    0.00                              /* j=2 */
    0.18    0.18    0.15    0.00    0.00                              /* j=3 */
    0.18    0.18    0.18    0.00    0.00                              /* j=4 */
    0.00    0.00    0.00    0.00    0.00                              /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                              /* j=1 */
    0.00   -0.10    0.00    0.00    0.00                              /* j=2 */
    0.00    0.00   -0.10    0.00    0.00                              /* j=3 */
    0.00    0.00    0.00    0.00    0.00                              /* j=4 */
    0.00    0.00    0.00    0.00    0.00                              /* j=5 */
    0.04    0.04    0.04    0.00    0.00                              /* j=6 */

********************************************************************************
# of products in cooktop     =    2

================================================================================
product type id#             =   12
product name                 = ECKT (Electric Cooktop)
end-use id#                  =    7
fuel type id#                =    1
number of classes            =    2

---------- the 1st class -------------------------------------------------------
class id#                    =   36
class name                   = Coil (Electric Cooktop, Coil Element)
discount rate                = 0.15
last year of historical EF   = 1991
first year for eff level     = 2016
```

```
UEC of eff level             =   271.1
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .737    .737    .737    .737    .737    .737    .737    .737    .737    .737    .737

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85    0.85
    0.85    0.85    0.85    0.85    0.85

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                     Maint
  179.09  234.74                                  0.737                      0.00
  183.90  225.21                                  0.769                      0.00
  190.79  222.90                                  0.777                      0.00

---------- Shipment Distribution (source: none)
      EF   Units
    .737      1.

---------- the 2nd class ---------------------------------------------------------
class id#                    =   37
class name                   = Smth (Electric Cooktop, Smooth Element)
discount rate                = 0.15
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   293.7
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .742    .742    .742    .742    .742    .742    .742    .742    .742    .742    .742

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15    0.15
    0.15    0.15    0.15    0.15    0.15

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                     EF                     Maint
  279.68  233.38                                  0.742                      0.00
  738.77  229.84                                  0.753                      0.00
 1057.24  206.39                                  0.839                      0.00

---------- Shipment Distribution (source: none)
     Kwh   Units
    .742      1.
```

```
================================================================================
product type id#             =   13
product name                 = GCKT (Gas Cooktop)
end-use id#                  =    7
fuel type id#                =    2
number of classes            =    1

---------- the 1st class ------------------------------------------------------
class id#                    =   38
class name                   = Gas Cooktop
discount rate                = 0.50
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =  3.7581
conversion (usage)           =   1.000

---------- Historical energy factors (starting from .85 w/o IID to .083 w/o IID in 1991)
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .193    .212    .230    .249    .267    .286    .305    .323    .342    .360    .379

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu     kWH                         EF                      Maint
  218.80  3.3728    0.00                     0.1564                       0.00
  261.76  1.3230    0.00                     0.3988                       7.25
  299.42  1.2574    0.00                     0.4196                       7.25
  312.67  1.2559    0.00                     0.4201                       7.25

---------- Shipment Distribution (source: none)
      EF   Units
   .1564   1.0
```

```
Oven
total saturation              = 1.00
elec price multiplier         = 1.04
gas price multiplier          = 1.11
ncalc                         = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs)        = 0
nv5 (# of cap inputs)        = 0
nv2 (# of peq inputs)        = 0
nv4 (# of usage inputs)      = 0
ndis (year to forecast eff)  = 2

---------- UEC of stock unit in base year by fuel type i (MMBTU/yr)
       1       2       3       4       5
  3.3472    2.61    0.00    0.00    0.00                              ** SF **
  3.3472    2.61    0.00    0.00    0.00                              ** MF **
  3.3472    2.61    0.00    0.00    0.00                              ** MB **

---------- Purchase price of a reference unit ($1990) -------------------------
       1       2       3       4       5
  528.48  563.44    0.00    0.00    0.00                              ** SF **
  528.48  563.44    0.00    0.00    0.00                              ** MF **
  528.48  563.44    0.00    0.00    0.00                              ** MB **

---------- Relative UEC and Capacity of a reference unit to a stock unit -------
       1       2       3       4       5
    1.00    1.00    0.00    0.00    0.00                              ** re   **
    1.00    1.00    0.00    0.00    0.00                              ** recap**

---------- Base Year Saturations - c70 ----------------------------------------
       1       2       3       4       5       6
   0.600   0.380   0.000   0.000   0.000   0.020                      ** SF **
   0.460   0.500   0.000   0.000   0.000   0.040                      ** MF **
   0.440   0.520   0.000   0.000   0.000   0.040                      ** MB **

---------- Marginal Saturations for Replacement Units - cn(m=1) ----------------
       1       2       3       4       5       6
   0.540   0.450   0.000   0.000   0.000   0.010                      ** SF **
   0.380   0.600   0.000   0.000   0.000   0.020                      ** MF **
   0.200   0.770   0.000   0.000   0.000   0.030                      ** MB **

---------- Marginal Saturations for New Houses - cn(m=2) ----------------------
       1       2       3       4       5       6
   0.790   0.180   0.000   0.000   0.000   0.030                      ** SF **
   0.840   0.115   0.000   0.000   0.000   0.045                      ** MF **
   0.450   0.500   0.000   0.000   0.000   0.050                      ** MB **

---------- Historical Shipments (from 1980 to 30 years back) -------------------
 1 Electric Ovens
   2.351   2.266   2.361   2.592   2.943   2.872   2.511   2.253   2.327   2.193
   1.997   2.076   2.084   2.018   1.913   1.769   1.650   1.684   1.777   1.622
   1.709   1.893   1.896   1.698   1.645   1.620   1.927   2.050   1.718   1.984
 2 Gas Ovens
   2.211   2.132   2.221   2.438   2.768   2.702   2.362   2.119   2.189   2.063
   1.879   1.953   1.961   1.899   1.800   1.665   1.552   1.584   1.672   1.526
   1.608   1.781   1.783   1.598   1.548   1.524   1.813   1.929   1.616   1.867

---------- Retirement Function (from age 1 to 30 years) ------------------------
all i
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .1340   .2140   .2400   .2140   .1340
   .0640   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

---------- Average Life Times (by fuel type i) --------------------------------
       1       2       3       4       5
    19.0    19.0     0.0     0.0     0.0
```

```
---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    .105    0.00    0.00    0.00    0.00                       /* j=1 */
    0.09   -.135    0.00    0.00    0.00    0.00                       /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=3 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=5 */
    0.00    0.12    0.00    0.00    0.00   -.585                       /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.18    0.00    0.00    0.00                               /* j=1 */
    0.18    0.15    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00   -0.10    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */
    0.04    0.04    0.00    0.00    0.00                               /* j=6 */

********************************************************************************
# of products in oven        =    2

================================================================================
product type id#             =   14
product name                 = EOVN (Electric Oven)
end-use id#                  =    8
fuel type id#                =    1
number of classes            =    2

---------- the 1st class -------------------------------------------------------
class id#                    =   67
class name                   = EnSC (Electric Oven, non-Self-Cleaning)
discount rate                = 0.36
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   966.5
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066   .1066

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44    0.44
    0.44    0.44    0.44    0.44    0.44

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                      EF                 Maint
  399.08  274.94                                  0.1066                 0.000
  402.55  263.23                                  0.1113                 0.000
```

```
  410.08  251.78                                  0.1164                   0.000
  427.83  247.96                                  0.1182                   0.000
  577.83  169.57                                  0.1728                   0.000
  607.10  164.60                                  0.1780                   0.000
  704.68  162.70                                  0.1801                   0.000
  713.15  162.42                                  0.1804                   0.000

---------- Shipment Distribution (source: none)
      EF   Units
   .1089      1.

---------- the 2nd class --------------------------------------------------------
class id#                    =   68
class name                   = EwSC (Electric Oven, with-Self-Cleaning)
discount rate                = 0.36
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   398.9
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965   .0965

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56    0.56
    0.56    0.56    0.56    0.56    0.56

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                      EF                   Maint
  630.16  303.72                                  0.0965                   0.000
  817.31  220.02                                  0.1332                   0.000
  854.96  215.54                                  0.1359                   0.000
  867.53  215.27                                  0.1361                   0.000
  989.19  213.73                                  0.1371                   0.000

---------- Shipment Distribution (source: none)
     Kwh   Units
   .1138      1.

================================================================================
product type id#             =   15
product name                 = GOVN (Gas Oven)
end-use id#                  =    8
fuel type id#                =    2
number of classes            =    2

---------- the 1st class --------------------------------------------------------
class id#                    =   69
class name                   = GnSC (Gas Oven, non-self-cleaning)
discount rate                = 0.43
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   3.728
conversion (usage)           =   1.000 .003412

---------- Historical energy factors  (.15 in 1981 to .766 in 1991 have IID, wt eff
```

```
accordingly)
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0341   .0358   .0376   .0393   .0411   .0428   .0446   .0463   .0481   .0498   .0516

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76    0.76
    0.76    0.76    0.76    0.76    0.76

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu                                   EF                    Maint
  479.49   2.982    0.00                      0.02978                     0.00
  519.80   1.408   34.16                      0.05826                     0.00
  529.41   1.335   34.16                      0.06117                     0.00
  532.80   1.321   34.16                      0.06177                     0.00
  594.43   1.240   37.08                      0.06497                     0.00
  599.17   1.234   37.08                      0.06527                     0.00
  668.50   1.233   37.08                      0.06534                     0.00

---------- Shipment Distribution (source: none)
      EF   Units
  .02978   1.0

---------- the 2nd class ----------------------------------------------------------
class id#                    =   70
class name                   = GwSC (Gas Oven, with-self-cleaning)
discount rate                = 0.43
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   3.728
conversion (usage)           =   1.000 .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535   .0535

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015) (Source: AHAM, twc)
l = 1 2 3
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24    0.24
    0.24    0.24    0.24    0.24    0.24

---------- UEC (MMBTU) & Purchase Price ($1990) data
   Price   MMBtu                                   EF                    Maint
  829.27   1.432   66.68                       0.0535                     0.00
  864.86   1.190   69.70                       0.0622                     0.00
  878.73   1.184   69.70                       0.0624                     0.00
  882.30   1.176   69.70                       0.0628                     0.00
 1032.87   1.120   69.70                       0.0654                     0.00

---------- Shipment Distribution (source: none)
```

EF	Units
.0561	1.

```
Mwv Oven
total saturation             = 1.00
elec price multiplier        = 1.04
gas price multiplier         = 1.11
ncalc                        = 2
ndr1 (1, read drate & curve) = 0
nv1 (# of eun inputs)        = 0
nv5 (# of cap inputs)        = 0
nv2 (# of peq inputs)        = 0
nv4 (# of usage inputs)      = 0
ndis (year to forecast eff)  =10

---------- UEC of stock unit in base year by fuel type i (MMBTU/yr) -----------
       1       2       3       4       5
  1.6468    0.00    0.00    0.00    0.00                              ** SF **
  1.6468    0.00    0.00    0.00    0.00                              ** MF **
  1.6468    0.00    0.00    0.00    0.00                              ** MB **

---------- Purchase price of a reference unit ($1990) -------------------------
       1       2       3       4       5
  189.00    0.00    0.00    0.00    0.00                              ** SF **
  189.00    0.00    0.00    0.00    0.00                              ** MF **
  189.00    0.00    0.00    0.00    0.00                              ** MB **

---------- Relative UEC and Capacity of a reference unit to a stock unit -------
       1       2       3       4       5
    1.00    0.00    0.00    0.00    0.00                              ** re   **
    1.00    0.00    0.00    0.00    0.00                              ** recap**

---------- Base Year Saturations - c70 ----------------------------------------
       1       2       3       4       5       6
   0.190   0.000   0.000   0.000   0.000   0.810                      ** SF **
   0.110   0.000   0.000   0.000   0.000   0.890                      ** MF **
   0.160   0.000   0.000   0.000   0.000   0.840                      ** MB **

---------- Marginal Saturations for Replacement Units - cn(m=1) ----------------
       1       2       3       4       5       6
   0.900   0.000   0.000   0.000   0.000   0.100                      ** SF **
   0.850   0.000   0.000   0.000   0.000   0.150                      ** MF **
   0.900   0.000   0.000   0.000   0.000   0.100                      ** MB **

---------- Marginal Saturations for New Houses - cn(m=2) ----------------------
       1       2       3       4       5       6
   0.770   0.000   0.000   0.000   0.000   0.230                      ** SF **
   0.580   0.000   0.000   0.000   0.000   0.420                      ** MF **
   0.580   0.000   0.000   0.000   0.000   0.420                     ** MB **

---------- Historical Shipments (from 1980 to 30 years back) -------------------
 1 Electric
  3.608   2.807   2.501   2.157   1.749   1.052    .713    .445    .314      0.
      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

---------- Retirement Function (from age 1 to 30 years) ------------------------
all i
   .0000   .0000   .0000   .0000   .0000   .0000   .0320   .1340   .2140   .2400
   .2140   .1340   .0320   .0000   .0000   .0000   .0000   .0000   .0000   .0000
   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

---------- Average Life Times (by fuel type i) ---------------------------------
       1       2       3       4       5
    10.0     0.0     0.0     0.0     0.0

---------- Operating Cost Elasticities (for 5 fuel types and income) -----------
       1       2       3       4       5       6
   -0.15    0.00    0.00    0.00    0.00    0.00                     /* j=1 */
```

```
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=2 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=3 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=4 */
    0.00    0.00    0.00    0.00    0.00    0.00                       /* j=5 */
    0.00    0.00    0.00    0.00    0.00   -.585                       /* j=6 */

---------- Interest Rate used to calculate Price Elasticities ------------------
       1       2       3       4       5
    0.15    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00    0.00    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */

---------- Usage Elasticities (for 5 fuel types and income) --------------------
       1       2       3       4       5
   -0.10    0.00    0.00    0.00    0.00                               /* j=1 */
    0.00    0.00    0.00    0.00    0.00                               /* j=2 */
    0.00    0.00    0.00    0.00    0.00                               /* j=3 */
    0.00    0.00    0.00    0.00    0.00                               /* j=4 */
    0.00    0.00    0.00    0.00    0.00                               /* j=5 */
    0.04    0.00    0.00    0.00    0.00                               /* j=6 */

********************************************************************************
# of products in Microwave   =    1

================================================================================
product type id#             =   16
product name                 = Micr (Microwave Oven)
end-use id#                  =    9
fuel type id#                =    1
number of classes            =    1

---------- the 1st class -------------------------------------------------------
class id#                    =   71
class name                   = Micr (Microwave Oven)
discount rate                = 0.50
last year of historical EF   = 1991
first year for eff level     = 2016
UEC of eff level             =   966.5
conversion (Kwh-MMBTU&usage) = .003412

---------- Historical energy factors
    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990    1991
    .557    .557    .557    .557    .557    .557    .557    .557    .557    .557    .557

---------- Adjusted volumes (1981-2015)
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0

---------- Fraction of market share (1981-2015)
l = 1 2 3
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
    1.00    1.00    1.00    1.00    1.00

---------- UEC (Kwh) & Purchase Price ($1990) data
   Price     Kwh                                    EF                 Maint
  189.00  143.20                                 0.557                  0.00
  195.88  136.11                                 0.586                  0.00
  208.69  135.58                                 0.588                  0.00
  228.83  133.54                                 0.597                  0.00
  254.50  132.43                                 0.602                  0.00
```

```
---------- Shipment Distribution (source: none)
      EF   Units
    .557      1.
```

Figure A.1 Annual Electric Cooking Energy Consumption

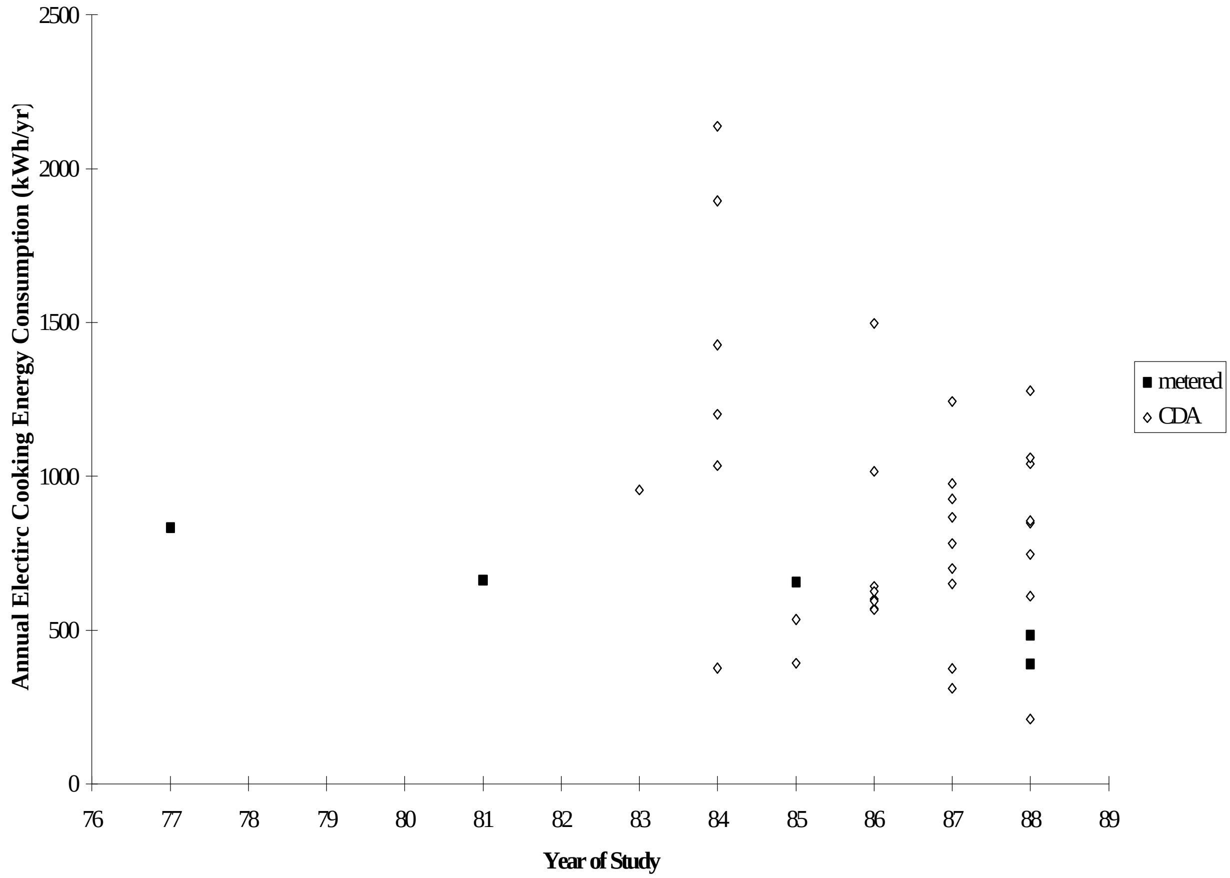

Figure A.2 Annual Gas Cooking Energy Consumption

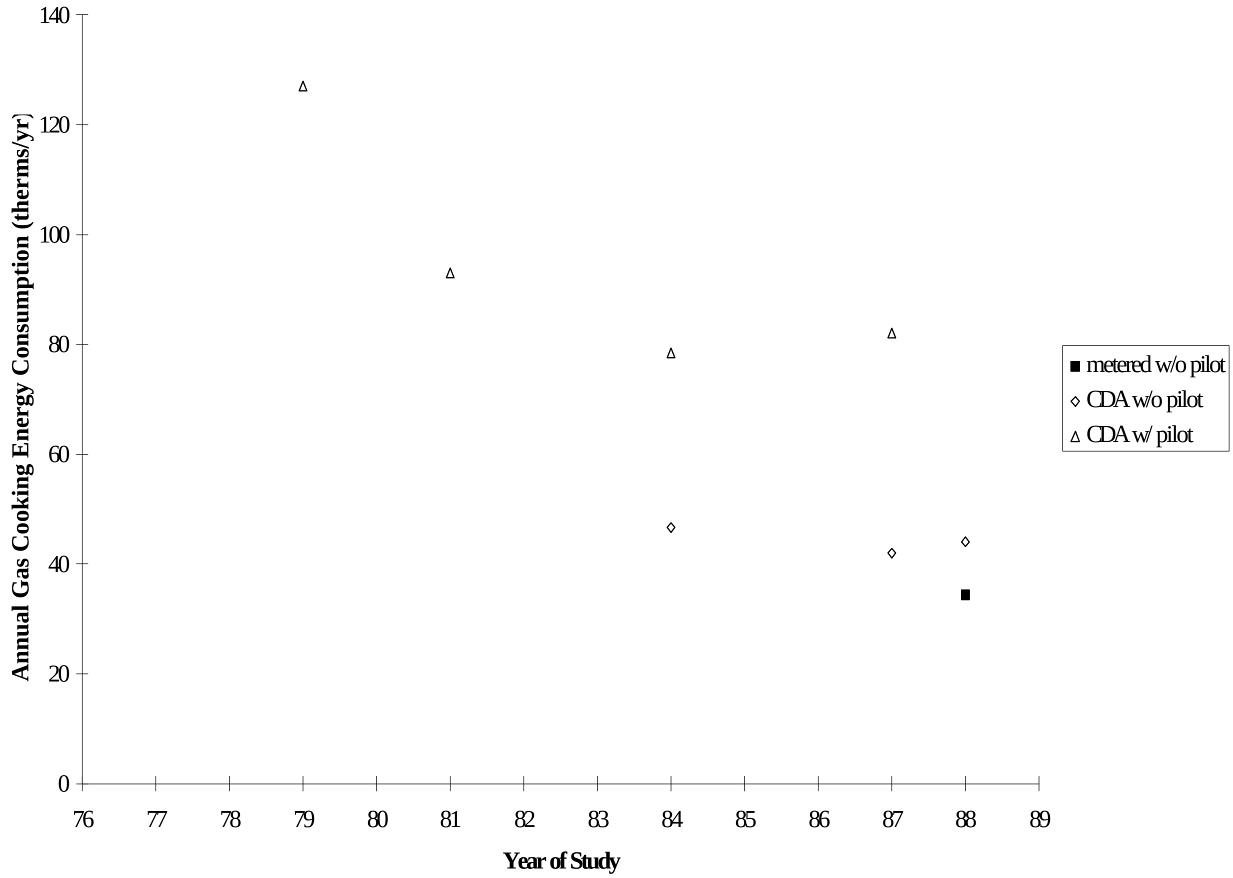

Table A.1 Annual Electric Cooking Energy Consumption[1]

Source	Year	Cooktop	Oven	Range	Units	Type
SCE	88			390.0	kWh	meter
Sierra	88			484.0	kWh	meter
PG&E	85	322.0	334.0	656.0	kWh	meter
Potomac	81			662.0	kWh	meter
MRI	77	589.8	496.8	833.3	kWh	meter
AEP	88			1040.0	kWh	CDA
BG&E	88			610.0	kWh	CDA
BSG/XENERGY	88			210.0	kWh	CDA
Sierra	88			848.0	kWh	CDA
TNP	88			1060.0	kWh	CDA
NMPC	88			1278.0	kWh	CDA
LILCO	88			745.0	kWh	CDA
PSE&G	88			855.0	kWh	CDA
CEC	87			650.0	kWh	CDA
CommEd	87			310.0	kWh	CDA
El Paso	87			866.0	kWh	CDA
JCP&L	87			926.0	kWh	CDA
MetEd	87			782.0	kWh	CDA
PG&E	87			375.0	kWh	CDA
VEPCO	87			1243.0	kWh	CDA
ACEEE	87			700.0	kWh	CDA
REEPS	87			976.0	kWh	CDA
FP&L	86			568.0	kWh	CDA
Gulf	86			1015.0	kWh	CDA
NPC	86			642.0	kWh	CDA
NYSEG	86			600.0	kWh	CDA
PG&E	86			625.0	kWh	CDA
PG&Ea	86			566.0	kWh	CDA
RG&E	86			593.0	kWh	CDA
TVA	86			1498.0	kWh	CDA
PG&E	85			392.0	kWh	CDA
SDG&E	85			534.0	kWh	CDA
AP&L	84			1896.0	kWh	CDA
LP&L	84			1202.0	kWh	CDA
MP&L	84			2138.0	kWh	CDA
MPC	84			1034.0	kWh	CDA
NOPS	84			1427.0	kWh	CDA
SDG&E	84			376.0	kWh	CDA
APC	83			955.0	kWh	CDA

[1] Due to the age of the data (from the years 1977 to 1988), the electric self-cleaning ovens represented by the data are assumed to be operated with the same self-clean cycles as in the existing DOE test procedure (11 cycles per year).

Table A.2 Annual Gas Cooking Energy Consumption[2]

Source	Year	Cooktop	Oven	Range	Units	Type	Pilot
SCE	88			34.4	therms	meter	no
BSG/XENERGY	88			44.0	therms	CDA	no
CEC	87			42.0	therms	CDA	no
SoCal	84			46.7	therms	CDA	no
REEPS	87			82.0	therms	CDA	yes
SoCal	84			78.4	therms	CDA	yes
SoCal	81			93.0	therms	CDA	yes
SoCal	79			127.0	therms	CDA	yes

The average annual useful cooking energy output for DOE's proposed test procedure was calculated from the following: 1) the above utility studies of annual energy consumption (shown in Tables A.1 and A.2), 2) DOE test procedure assumptions, 3) baseline cooktop and oven cooking efficiencies (as assumed in the technical analysis in support of the minimum efficiency standards proposed by DOE on March 4, 1994 for kitchen ranges and ovens (5)), and 4) market shares of oven types.

Gas Cooking

The calculations for gas cooking were based on an average annual cooking energy consumption of 41.8 therms reported by four recent studies[3] done in California. Because of the building code in California, the cooking equipment in these studies were assumed to have no standing pilot lights. Only these studies were used in the calculation to avoid having to correct for pilot light consumption. The average annual gas cooking energy consumption was assumed to equal the sales weighted average of standard and self-cleaning oven energy consumption plus the cooktop energy consumption.

$$
\begin{aligned}
UEC_{gas\ cooking} &= 41.8\ therms \\
&= MSg_{sc} \bullet UEC_{gas\ oven\ sc} \\
&+ (1 - MSg_{sc}) \bullet UEC_{gas\ oven} \\
&+ UEC_{gas\ cooktop}
\end{aligned}
\tag{A.1}
$$

where,

MSg_{sc} = the market share of gas ovens that are self-cleaning, 23.74% (6),

[2] Due to the age of the data (from the years 1979 to 1988), the gas self-cleaning ovens represented by the data are assumed to be operated with the same self-clean cycles as in the existing DOE test procedure (7 cycles per year).

[3] These are the studies listed as SCE '88, BSG/Xenergy '88, CEC '87, SoCal '84 for gas in Table A.2.

$UEC_{gas\ oven\ sc}$ = unit energy consumption for self-cleaning gas ovens,
$UEC_{gas\ oven}$ = unit energy consumption for standard gas ovens,
$UEC_{gas\ cooktop}$ = unit energy consumption for gas cooktops.

The average energy consumption of self-cleaning ovens was estimated as a fraction of the energy consumption of a standard gas oven plus the self-cleaning energy. The average energy consumption of cooktops was estimated as a fraction of the energy consumption of standard ovens. These fractions were from the ratios of energy consumption in the DOE test procedure. This was done to determine unit energy consumption of self-cleaning ovens and cooktops as a function of the unit energy consumption of the standard gas oven. The formulas for this are:

$$UEC_{gas\ oven\ sc} = Rg_{sc\ std} \bullet UEC_{gas\ oven} + E_{gs} \bullet S_g \qquad \textbf{(A.2)}$$

and,

$$UEC_{gas\ cooktop} = Rg_{ct\ std} \bullet UEC_{gas\ oven} \qquad \textbf{(A.3)}$$

where,

$Rg_{sc\ std}$ = the ratio of self-cleaning gas oven cooking energy to standard gas oven cooking energy,

$Rg_{ct\ std}$ = the ratio of gas cooktop cooking energy to standard gas oven cooking energy,

E_{gs} = typical self-cleaning energy consumption per cycle for gas self-cleaning ovens, 0.459 therms,

S_g = number of self-clean cycles per year for gas ovens, 7 from DOE (7)[4].

For the purposes of calculating these ratios, the self-cleaning gas oven cooking energy, the gas cooktop cooking energy, and the standard gas oven cooking energy were calculated as the DOE annual useful cooking energy output divided by the baseline cooking efficiency reported in the cost/efficiency tables (Chapter 1, Sections 1.3.3 and 1.4.3). This assumes the ratio of annual useful cooking energy output for cooktops compared to ovens has not changed significantly.

[4] For purposes of calculating a revised value for the annual useful cooking energy output for the proposed DOE test procedure, the number of self-clean cycles was assumed to be 7 for gas ovens. As reported in the Executive Summary of Volume 2 of this TSD, more recent data indicates that the number of self-clean cycles should be 4. But for the years in which the data used in these calculations are based (1984 through 1988), 7 self-clean cycles are assumed to be a more representative value.

$$Rg_{sc\ std} = \frac{(Oo_{DOE} / EFFgo_{SC})}{(Oo_{DOE} / EFFgo_{std})} = 0.827 \qquad \textbf{(A.4)}$$

$$Rg_{ct\ std} = \frac{(Oct_{DOE} / EFFg_{ct})}{(Oo_{DOE} / EFFgo_{std})} = 0.872 \qquad \textbf{(A.5)}$$

where,

Oo_{DOE} = the annual useful cooking energy output for ovens according to the old DOE test procedure (8), 1.607 therms,

Oct_{DOE} = the annual useful cooking energy output for cooktops according to the old DOE test procedure (9), 9.475 therms,

$EFFgo_{SC}$ = the cooking efficiency of the baseline self-cleaning gas oven, from the cost/efficiency table, 7.13%,

$EFFgo_{std}$ = the cooking efficiency of the baseline standard gas oven, from the cost/efficiency table, 5.9%,

$EFFg_{ct}$ = the cooking efficiency of the baseline gas cooktop, from the cost/efficiency table, 39.9%.

At this point Eq. A.1 for the unit energy consumption for gas cooking can be rewritten so the only unknown variable is the unit energy consumption of a standard gas oven. This is done as follows:

$$\begin{aligned} UEC_{gas\ cooking} = {} & MSg_{sc} \bullet (Rg_{sc} \bullet UEC_{gas\ oven} + Egs \bullet Sg) \\ & + (1 - MSg_{sc}) \bullet UEC_{gas\ oven} \\ & + Rg_{ct\ std} \bullet UEC_{gas\ oven} \end{aligned} \qquad \textbf{(A.6)}$$

Solving this equation for the unit energy consumption of standard gas ovens yields 21.1 therms, as shown in the following equation,

$$UEC_{gas\ oven} = \frac{UEC_{gas\ cooking} - Egs \bullet Sg}{(MSg_{sc} \bullet (Rg_{sc\ std} - 1) + Rg_{ct\ std} + 1)} = 21.1\ therms \qquad \textbf{(A.7)}$$

The unit energy consumption of the standard gas oven is the annual useful oven cooking energy output divided by the efficiency of the average standard gas ove
n. Using the baseline efficiency from the cost/efficiency table and solving for the annual useful oven cooking energy output gives 1.24 therms.

$$Oo_{adj} = UEC_{gas\ oven} \bullet EFFgo_{std} = 1.24\ therms \qquad \textbf{(A.8)}$$

The ratio of gas cooktop energy consumption to standard gas oven energy consumption from Eq. A.5 and the baseline efficiency of the gas cooktop from the cost/efficiency table were used to determine the annual useful cooktop cooking energy output of 7.32 therms.

$$Oct_{adj} = Rg_{ct\ std} \bullet UEC_{gas\ oven} \bullet EFFg_{ct} = 7.32\ therms \qquad \textbf{(A.9)}$$

Electric Cooking

The calculations for electric cooking were done in a similar manner as gas cooking. The unit energy consumption for electric cooking was the average annual electric cooking energy consumption of 605.1 kWh reported by five utility metering studies[5] done from 1977 to 1988. Metering studies measure cooking energy consumption directly, giving a better measure than conditional demand analysis studies. The average annual cooking energy consumption was assumed to equal the sales weighted average of standard and self-cleaning oven energy consumption and the cooktop energy consumption.

$$\begin{aligned} UEC_{elec\ cooking} &= 605.1\ kWh \\ &= MSe_{sc} \bullet UEC_{elec\ oven\ sc} \\ &+ (1 - MSe_{sc}) \bullet UEC_{elec\ oven} \\ &+ UEC_{elec\ cooktop} \end{aligned} \qquad \textbf{(A.10)}$$

[5] These are the studies listed as SCE '88, Sierra '88, PG&E '85, Potomac '81, and MRI '77 for electricity in Table A.1.

where,

MSe_{sc} = the market share of electric ovens that are self-cleaning, 55.6% (10),

$UEC_{elec\ oven\ sc}$ = unit energy consumption for self-cleaning electric ovens,

$UEC_{elec\ oven}$ = unit energy consumption for standard electric ovens,

$UEC_{elec\ cooktop}$ = unit energy consumption for electric cooktops.

The average energy consumption of electric self-cleaning ovens was estimated as a fraction of the energy consumption of a standard electric oven plus the self-cleaning energy. The average energy consumption of cooktops was estimated as a fraction of the energy consumption of standard ovens. These fractions were from the ratios of energy consumption in the DOE test procedure. This was done to determine unit energy consumption of self-cleaning ovens and cooktops as a function of the unit energy consumption of the standard electric oven. The formulas for this are:

$$UEC_{elec\ oven\ sc} = Re_{sc\ std} \bullet UEC_{elec\ oven} + Ees \bullet S_e \qquad \textbf{(A.11)}$$

and,

$$UEC_{elec\ cooktop} = Re_{ct\ std} * UEC_{elec\ oven} \qquad \textbf{(A.12)}$$

where,

$Re_{sc\ std}$ = the ratio of self-cleaning electric oven cooking energy to standard electric cooking energy,

$Re_{ct\ std}$ = the ratio of electric cooktop cooking energy to standard electric oven cooking energy,

Ees = typical self-cleaning energy consumption per cycle for electric self-cleaning ovens, 5.5 kWh,

S_e = number of self-clean cycles per year for electric ovens, 11 from DOE (11)[6].

For the purposes of calculating these ratios, the self-cleaning electric oven cooking energy, the electric cooktop cooking energy, and the standard electric oven cooking energy were calculated as the DOE annual

[6] For purposes of calculating a revised value for the annual useful cooking energy output for the proposed DOE test procedure, the number of self-clean cycles was assumed to be 11 for electric ovens. As reported in the Executive Summary of Volume 2 of this TSD, more recent data indicates that the number of self-clean cycles should be 4. But for the years in which the data used in these calculations are based (1977 through 1988), 11 self-clean cycles are assumed to be a more representative value.

useful cooking energy output divided by the baseline cooking efficiency reported in the cost/efficiency tables (Chapter 1, Sections 1.3.3 and 1.4.3). This assumes the ratio of annual useful cooking energy output for cooktops compared to ovens has not changed significantly.

$$Re_{sc\ std} = \frac{(Oo_{DOE} / EFFeo_{SC})}{(Oo_{DOE} / EFFeo_{std})} = .871 \qquad \textbf{(A.13)}$$

$$Re_{ct\ std} = \frac{(Oct_{DOE} / EFFe_{ct})}{(Oo_{DOE} / EFFeo_{std})} = .924 \qquad \textbf{(A.14)}$$

where,

Oo_{DOE}	=	the annual useful cooking energy output for ovens according to the old DOE test procedure (12), 47.1 kWh,
Oct_{DOE}	=	the annual useful cooking energy output for cooktops according to the old DOE test procedure (13), 277.7 kWh,
$EFFeo_{SC}$	=	the cooking efficiency of the baseline self-cleaning electric oven, from the cost/efficiency table, 13.9%,
$EFFeo_{std}$	=	the cooking efficiency of the baseline standard electric oven, from the cost/efficiency table, 12.1%,
$EFFe_{ct}$	=	the cooking efficiency of the baseline electric cooktop, from the cost/efficiency table, 77.2%,

At this point, Eq. A.10 for the unit energy consumption for electric cooking can be rewritten so the only unknown variable is the unit energy consumption of a standard electric oven. This is done as follows:

$$\begin{aligned} UEC_{elec\ cooking} &= MSe_{sc} \bullet (Re_{sc} \bullet UEC_{elec\ oven} + Ees \bullet Se) \\ &+ (1 - MSe_{sc}) \bullet UEC_{elec\ oven} \\ &+ Re_{ct\ std} \bullet UEC_{elec\ oven} \end{aligned} \qquad \textbf{(A.15)}$$

Solving this equation for the unit energy consumption of standard electric ovens yields 293.4 kWh, as shown in the following equation,

$$UEC_{elec\ oven} = \frac{UEC_{elec\ cooking} - Ees \bullet Se}{MSe_{sc} \bullet (Re_{sc\ std} - 1) + Re_{ct\ std} + 1} = 293.4\ kWh \qquad \textbf{(A.16)}$$

The unit energy consumption of the standard electric oven is the annual useful oven cooking energy output divided by the efficiency of the average standard electric oven. Using the baseline efficiency from the cost/efficiency tables and solving for the annual useful oven cooking energy output (Oo_{adj})gives 35.5 kWh.

$$Oo_{adj} = UEC_{elec\ oven} \bullet EFFeo_{std} = 35.5\ kWh \qquad \textbf{(A.17)}$$

The ratio of electric cooktop energy consumption to standard electric oven energy consumption from Eq. A.5 and the baseline efficiency of the electric cooktop from the cost/efficiency table were used to determine the annual useful cooktop cooking energy output (Oct_{adj}) of 209.4 kWh.

$$Oct_{adj} = Re_{ct\ std} \bullet UEC_{elec\ oven} \bullet EFFe_{ct} = 209.4\ kWh \qquad \textbf{(A.18)}$$

The annual useful cooktop and oven cooking energy outputs were all converted to kBtu to compare with the original values specified in the DOE test procedure. These values are listed in Table A.3. It is encouraging that annual useful cooking energy outputs for gas and electric products are so close to one another.

Table A.3 Comparison of Annual Useful Cooking Energy Outputs

	DOE (kBtu)	gas (kBtu)	electric (kBtu)
Oven	160.7	124.2	121.2 (35.5 kWh)
Cooktop	947.5	732.5	714.3 (209.4 kWh)

A.1.1 Notes for Table A.1 Annual Electric Cooking Energy Consumption

DOE

This is energy consumption using the unadjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by (Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. The annual energy consumption for an electric coil cooktop was from Table 1.4 Cost-Efficiency Table for Coil Cooktops. The annual energy consumption for a standard electric oven was from Table 1.9 Cost-Efficiency Table for Standard Electric Ovens. The annual energy consumption for a self-cleaning electric oven was from Table 1.10 Cost-Efficiency Table for Self-Cleaning Electric Ovens.

Adjusted

This is energy consumption using the adjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by (Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. The annual energy consumption for an electric coil cooktop was from Table 1.4 Cost-Efficiency Table for Coil Cooktops. The annual energy consumption for a standard electric oven was from Table 1.9 Cost-Efficiency Table for Standard Electric Ovens. The annual energy consumption for a self-cleaning electric oven was from Table 1.10 Cost-Efficiency Table for Self-Cleaning Electric Ovens.

SCE (elec)

Data is metered data from the Residential Energy Usage Comparison project by Southern California Edison Company and EPRI. It is based on a sample of 92 households in Orange County, California. From Smith, B.A., Uhlaner, R.T. and Cason, T.N. "Residential Energy Usage Comparison Project: An Overview", Quantum Consulting Inc., Berkeley, CA, October 1990, prepared for Southern California Edison Company and EPRI, CU-6952, Research Project 2863-3, Table 3-1, Average Annual and Seasonal Energy Usage for Orange County Sample Households, p 3-5.

Sierra, metered (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 4-3, Sierra Pacific Validation Study, p 4-4. This data is from Wright, Roger L. and Curt D. Puckett. "Integrating EIP and HES5 Information for Estimating End-Use Energies. Prepared for Sierra Pacific Power Company, March 1988.

PG&E (AMP)

This study is from end-use metered residential appliances during 1985 and 1986. Brodsky, Joel B. and Susan E. McNicoll;"Residential Appliance Load Study, 1985-1986"; Appliance Metering Project; Regulatory Cost of Service Department; Pacific Gas and Electric Company, September 1987; Table 4-1; "Annual Electricity UEC Estimates", p 4-5.

Potomac

This data was from Applications Engineering & Research, "Domestic Electric Range & Clothes Dryer Usage Study", Potomac Edison Company, July 1981. This is a two-page summary letter.

MRI

Data is from Lawrence, A.G. and Ignelzi, P.C. "Electric Appliance Energy Consumption Survey: Analysis and Revision of the MRI Data", Cambridge Systematic, Inc., Berkeley CA, September 1982, prepared for EPRI, EA-2565, Research Project 576-2, Table 8, "The Marginal Distributions of Energy Use for Electric Appliances Metered by MRI", p 4-3.

AEP (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

BG&E (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

BSG/XENERGY (elec)

"Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

Sierra (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of

Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

TNP (88)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NMPC

"Demand-Side Management Plan 1988"; Niagara Mohawk Power Corp.; Syracuse, NY, April 1988. As cited in draft RCG/Hagler, Bailly study.

LILCO

Barakat, Howard and Chamberlin, Inc.; "Demand-Side Management Program Analysis"; Long Island Lighting Co.: Berkeley, CA; April 1988. As cited in draft RCG/Hagler, Bailly study.

PSE&G

Public Service Electric & Gas; "1988 Corporate Energy Forecast"; PSE&G; Newark, NJ,; 1988. As cited in draft RCG/Hagler, Bailly study.

CEC (elec)

The 1987 marginal UECs from Forecasting Division, California Energy Commission, "Electricity Report #8, CEC, Sacramento, CA as listed in "Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

CommEd (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

El Paso (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

JCP&L (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

MetEd (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

VEPCO (87)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

ACEEE

Geller, H. et al.; "Acid Rain and Electricity Conservation"; American Council for an Energy-Efficient Economy; Wash DC; June 1987. As cited in draft RCG/Hagler, Bailly study.

REEPS

Cambridge Systematics; "REEPS Code: User's Guide"; Electric Power Research Institute; Palo Alto, CA; 1987. As cited in draft RCG/Hagler, Bailly study.

FP&L (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

Gulf (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NPC (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NYSEG (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&Ea (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

RG&E (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19. A footnote in the table indicated this cooking UEC was without microwave.

TVA (86)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

PG&E (85)

This data was taken from the same table as the PG&E AMP data. These are preliminary values supplied by the Market Research and Information Section of the Market Planning and Research Department.

SDG&E (85)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

AP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

LP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

MP&L (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

MPC (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

NOPS (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-11, Cooking UECS: Single-Family Dwellings, p 3-20.

SDG&E (84)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

APC (83)

Listed in Sebold, F.D. and Parris, K.M., "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", Regional Economic Research, Inc, San Diego, CA, October 1989 for EPRI, CU-6487, Research Project 2547-1, Table 3-10, Cooking UECS: All Dwellings, p 3-19.

A.1.2 Notes for Table A.2 Annual Gas Cooking Energy Consumption

DOE

This is energy consumption using the unadjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by(Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE. 26.63% of cooktops had standard pilot ignition. The remainder had electronic ignition. 23.74% of ovens were self-cleaning, 28.14% had power cords but were not self-cleaning, and 48.12% were standard ovens with out power cords.

The annual energy consumption of the of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the unadjusted annual useful cooking energy output. The annual energy consumption for the oven was the baseline from Table 1.12 Cost-Efficiency Table for Self-Cleaning Ovens using the unadjusted annual useful cooking energy output.

The energy consumption for the cooktop with standing pilots was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the unadjusted annual useful cooking energy output. The energy consumption for the standard gas oven was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens using the unadjusted annual useful cooking energy output.

Adjusted

This is energy consumption using the adjusted annual useful cooking energy output for coil cooktops and self-cleaning and standard ovens weighted by sales data supplied by(Wayne Hamilton, AHAM, 3/30/90 in letter to Michael McCabe, DOE.

26.63% of cooktops had standard pilot ignition. The remainder had electronic ignition. 23.74% of ovens were self-cleaning, 28.14% had power cords but were not self-cleaning, and 48.12% were standard ovens with out power cords.

The annual energy consumption of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The annual energy consumption for the self-cleaning gas oven was the baseline from Table 1.12 Cost-Efficiency Table for Self-Cleaning Ovens using the adjusted annual useful cooking energy output.

These values are the annual energy consumption for an gas cooktop with electronic ignition and a standard gas oven also . The annual energy consumption of the of the cooktop with electronic ignition was the baseline cooktop energy consumption minus the difference between the electronic ignition design option and the previous design option. The cooktop energy consumption was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The annual energy consumption for the oven with electronic ignition was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens. This is the annual energy consumption of the baseline minus the difference between electronic ignition and the previous design option.

The energy consumption for the cooktop with standing pilots was from Table 1.6 Cost-Efficiency Table for Standard Gas Cooktops using the adjusted annual useful cooking energy output. The energy consumption for the oven with standing pilots was from Table 1.11 Cost-Efficiency Table for Standard Gas Ovens using the adjusted annual useful cooking energy output.

SCE (gas)

Data is metered data from the Residential Energy Usage Comparison project by Southern California Edison Company and EPRI. It is based on a sample of 92 households in Orange County, California. From Smith, B.A., Uhlaner, R.T. and Cason, T.N. "Residential Energy Usage Comparison Project: An Overview", Quantum Consulting Inc., Berkeley, CA, October 1990, prepared for Southern California Edison Company and EPRI, CU-6952, Research Project 2863-3, Table 3-1, Average Annual and Seasonal Energy Usage for Orange County Sample Households, p 3-5.

BSG/XENERGY (gas)

"Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

CEC (gas)

Are the 1987 marginal UEC's from Forecasting Division, California Energy Commission, "Electricity Report #8, CEC, Sacramento, CA as listed in "Occupancy Patterns & Energy Consumption in New California Houses (1984-1988)" September 1990, prepared for California Energy Commission, Table 8-3, Average UECs for All New California Houses, p 8-9.

SoCal (84 w/o pilots)

Is conditional demand estimates for single family homes in southern California. This data is from Van Lierop, Johannes and Parris, Kenneth M. "Appliance Saturations and Gas Use in the Single-Family Sector", Regulatory Affairs Department, Southern California Gas Company, Los Angeles, CA February, 1988, Table 8. Comparison of Single Family UEC's 20-year Weather, p 4-8. The data for units w/o pilots was for houses built after 1979, when Title-24 went into effect, banning standing pilots in ranges and ovens.

REEPS

Cambridge Systematics; "REEPS Code: User's Guide"; Electric Power Research Institute; Palo Alto, CA; 1987. As cited in draft RCG/Hagler, Bailly study.

SoCal (84 w/pilots)

Is conditional demand estimates for single family homes in southern California. This data is from Van Lierop, Johannes and Parris, Kenneth M. "Appliance Saturations and Gas Use in the Single-Family Sector",Regulatory Affairs Department, Southern California Gas Company, Los Angeles, CA February, 1988, Table 8. Comparison of Single Family UEC's 20-year Weather, p 4-8. This was for houses built before 1979, the year Title-24 went into effect, banning standing pilots in new ranges.

SoCal (81)

Is from Parti, Michael, et al "Residential Appliance Energy Consumption in the Southern California Gas Company Service Territory: A Conditional Energy Demand Analysis",Applied Econometrics, Inc., submitted to Southern California Gas Co., August 1983, p 2.

SoCal (79)

Is from Parti, Michael, et al "Residential Appliance Energy Consumption in the Southern California Gas Company Service Territory: A Conditional Energy Demand Analysis",Applied Econometrics, Inc., submitted to Southern California Gas Co., August 1983, p 2.

A.2 RECENT DATA FOR ANNUAL USEFUL COOKING ENERGY OUTPUT

Background

In the testimony given during public hearings on the NOPR and also in written comments, DOE's estimates for annual energy consumption were criticized as not being current and, as a result, being too high for all cooking products including microwave ovens. The analysis in this section is an attempt to address this criticism. Additionally, the analysis projections within this TSD (i.e., consumer forecasting, life-cycle costs, manufacturer impact, utility impact, and environmental impact) are improved by using the most recent energy usage for a given appliance. These analyses compute projections and forecasts many years into the future. Hence, current energy usage data makes these projections more accurate. This is in comparison to using the annual energy usage values prescribed in the proposed DOE test procedure, which by law are required to be used in the engineering cost-benefit analysis and the determination of design option payback periods, i.e., the effects of various design options on energy consumption must be based on the existing test procedure which includes a prescribed national average energy consumption for each product class. By contrast, the consumer analysis, the life-cycle costs, the manufacturing impact analysis, the utility analysis, and the environmental impact analysis used current, and in effect lower annual energy consumption values than the engineering cost-benefit analysis in Chapter 1 and the payback period analysis in Chapter 4. So as to provide a comparison as to how the various design options analyzed affect cooking product energy use, the engineering cost-benefit analysis in Chapter 1 and the payback period analysis in Chapter 4 were also conducted with the lower annual energy consumption values in addition to those prescribed by the proposed DOE test procedure.

Approach

Several recent studies were analyzed to generate annual energy usage for cooking products. Table A.4 shows a summary of these current annual energy consumption values. Table A.5 shows that this new data consists primarily of recent metered studies, but does include some conditional demand analysis (CDA) estimates. For estimates of electric cooktops and ovens, and also for gas cooktops and ovens, only metered data from 1988 or earlier were included in the estimate. Due to the limited data available for microwave ovens, both CDA and metered study data were included. The trends in cooking usage are clearly headed downward. There is some indication that there are regional and year-to-year effects in cooking usage. No regional effects were included in this analysis. However, it should be noted that in Table A.5 the metered data for the same sample size and location for microwave oven usage increased from 68 to 114 kWh/y in one year (1990 to 1991 respectively; SoCal Edison; sample size of 48). This represents a 40 % increase in microwave oven usage in one year at the same location and with the same metered sample group. There is insufficient data to show whether this is actually a trend or merely an anomaly, i.e., the sample size may be too small to represent the actual usage over a short period of time. Nor should it be concluded that microwave annual usage is increasing in general. It does suggest that a single metered study for annual energy usage may not be representative of the location where the study was done and also may not represent the national average, e.g., written testimony submitted to DOE suggested that the 1988 Sierra data showing 77 kWh/y be used to represent the national average. Clearly more metered studies in more regions of the country over longer periods of time are needed to refine this estimate.

Annual energy consumption was computed for electric ranges, gas ranges, and microwave ovens. For the electric and gas ranges, only metered study data were used to produce the consumption value. The values were sample-weighted, i.e., the sample size was factored into the calculation. For the microwave oven consumption estimate, a different approach was used. Since there were only three metered studies, and two of them showed a 40 % difference within the same study group one year apart, CDA data were also included to help broaden the data base. Table A.5 shows the summary of the consumption analysis.

The average energy consumption values for the electric range and gas range had to be broken down further to yield oven and cooktop annual useful cooking energy outputs. Using the same equations and procedures described in Section A.1, the annual useful cooking energy outputs for electric and gas ovens and cooktops were computed using the most recent annual energy usage data. In accordance with data presented by the Gas Research Institute (14), the computations based on the most recent energy usage data also assumed four self-clean cycles per year for both electric and gas self-cleaning ovens. In addition, the cooking efficiencies of electric and gas ovens and cooktops were updated and set equal to the baseline efficiencies reported in Volume 2, Chapter 1 of this TSD. As shown in Table A.6, a summary of these calculations are reported for not only the most recent annual energy usage data (designated as Method 2), but also for the annual energy usage data that went into developing the annual useful cooking energy output values for the proposed DOE test procedure (designated as Method 1 and detailed in Appendix A.1). Both sets of calculations are presented for comparison purposes.

With regard to microwave ovens, the annual useful cooking energy output proposed by DOE for the microwave oven test procedure was calculated by taking the average annual consumption value of 143.2 kWh/yr (as reported in Table A.5) and multiplying it by an assumed microwave oven baseline efficiency of 54.0% (15). This yields an annual useful cooking energy output of 77.3 kWh/yr which is significantly different than the value of 34.2 kWh/yr reported in the existing DOE test procedure (16). The assumed microwave oven baseline efficiency of 54.0% was derived for the technical analysis that was conducted in support of the minimum efficiency standards proposed by DOE on March 4, 1994 for microwave ovens (17). As reported in Volume 2, Chapter 1 of this TSD, updated data indicates that the baseline efficiency is actually 55.7%. Using a baseline microwave oven efficiency of 55.7% yields an annual useful cooking energy output of 79.8 kWh/yr. This value of 79.8 kWh/yr represents the annual useful cooking energy output based on the most recent field data.

Results

The results of the energy consumption and annual useful cooking energy output analysis are shown below in Table A.4. As a means of further clarification of the annual useful cooking energy output values, Table A.7 has been included. This table shows the difference between annual useful cooking energy output values with regard to the existing DOE test procedure, the proposed DOE test procedure, and the recent energy usage data.

Table A.4 Summary of Annual Energy Consumption and Annual Useful Cooking Energy Output for Cooking Products based on Recent Usage Studies

	Annual Energy Consumption	Annual Useful Cooking Energy Output
GAS		
Range (MMBtu/yr)	6.32	Not Applicable
Oven (kBtu/yr)	Not Available	88.8
Cooktop (kBtu/yr)	Not Available	527.6
ELECTRIC		
Range (kWh/yr)	470.9	Not Applicable
Oven (kWh/yr)	Not Available	29.3
Cooktop (kWh/yr)	Not Available	173.1
Microwave Oven (kWh/yr)	143.2	79.8

Table A.5 Range and Oven Annual Cooking Energy Consumption, Recent Data

Reference[1]	Year of DATA	Type of DATA (Meter/CDA/ or Both)	Sample Size	ELECTRIC (kWh/y) RANGE		ELECTRIC OVEN	ELECTRIC CKTOP	MICROWAVE (kWh/y)		GAS (MMBtu/y) RANGE		GAS OVEN	GAS CKTOP	Comments
1993 TSD "Adjusted" [2]		Both			621.1	327.4	293.7		270		7.47	3.58	3.89	GAS numbers w/pilot; Current numbers in Proposed Test Procedures except for MW ovens
				Data Source Both	**Meter**			**Data Source Both**	**Meter**	**Data Source Both**	**Meter**			
1. GRI Report	1994	Meter	92							5.61	5.61	0.076*	0.4831*	w/pilot; Limited data/regional; *Energy "OUTPUT"
											2.24			w/o pilot; Limited data/regional; pilot = 3.37 MMBtu/y
2. AHAM/ADL	1992?	Both		449										Limited data/some included in TSD
3. EPRI (CU-6952)[5]	1990	Meter	92		390					6.81	6.81			SCE Data from '88;same as EPRI CU-7392;
Sierra[5]	1988	Meter	60		484									pilot added
Bonneville[5]	1992	Meter	318		472									
4. LBL-33717	1994	Both		816		386	485	132		5.61				Not all current/some date limited; 816 & 5.61 include CDA
Bonneville	1989	Meter	499		482									
Consum Pwr	1988?	Meter	9								5.71			Small sample size
5. EPRI (CU-7392)	1991	Meter	92	385						6.61	6.61			SCE Data from '88;(6.61=3.24+pilot); pilot=3.37=5.61-2.24
6. AEP/RECS	1992	Both		700				191		7.9				Limited data?/national;7.9 from '82 AGA
7. SoCal Edison	1991	Meter	48						114					91 "Res. Appl. End-Use Study Ann. Report"
8. SoCal Edison	1990	Meter	48						68					90 "Res. Appl. End-Use Study Ann. Report"
9. EPRI (CU-6487)	1989	CDA		743				277						Data in TSD
Sierra	1988	Meter	60		484				77					77 kWh/y not included in 277 CDA estimate and not included in TSD
					470.9 [3]						6.32 [3]			See Note 3
AVERAGE								143.2 [4]						See Note 4

References:

1 GRI Report: "Topical Report, Metered Ranges, Cooktops, and Ovens in the Northern Illinois Gas Residential Load Study Data Base", GRI-93/0204, July 1993
2 AHAM/ADL: "Electric Oven and Cooktop Data Analysis", Prepared for AHAM by ADL, Reference 47066, July 15, 1994
3 EPRI (CU-6952), "Residential Energy Usage Comparison Project: An Overview". October, 1990
4 LBL-33717, "Baseline Data for the Residential Sector and Development of a Residential Forecasting Database", May 1994.
5 EPRI (CU-7392), "Residential Energy Usage Comparison: Findings", August 1991.
6 AEP/RECS: AEP Report "Utility Estimates of Household Appliance Electricity Consumption" March 16, 1992, reported in RECS "Household Energy Consumption and Expenditures 1990", DOE/EIA-0321(90), February 1993.
7 & 8 So Cal Edison: "Residential Appliance End-Use Survey" for 1990 and 1991
9 EPRI (CU-6487), "Residential End-Use Energy Consumption: A Survey of Conditional Demand Estimates", October 1989

Notes:

1 Only data from sources dated 1988 to the present were used
2 Current numbers in Proposed test procedure except for MW ovens
3 Based on metered data from '88 or later; Average is sample weighted
4 Based on combination of metered and CDA data from 1988 to the present;Metered data not sample weighted due to small sample size
5 Studies included in AHAM/ADL report (Reference 2)

Table A.6 Range and Oven Annual Useful Cooking Energy Output Calculations[1]

GAS

Annual Energy Use (Therms)

		Method 1[2]	Method 2[3]
Gas Cooking, DATA[4]	=	41.8	29.5
Gas Cooking, CALCULATED	=	39.33	28.10
Gas Oven	=	21.056	15.08
Gas Oven, Self-Cleaning	=	20.68	14.36
Gas Cooktop	=	18.36	13.19

ANNUAL USEFUL COOKING ENERGY OUTPUT

		Method 1[2]	Method 2[3]	
		Therms	*Therms*	*kBtu*
Standard Oven	=	1.242	0.89	89.3
Cooktop	=	7.325	5.26	526.4

Inputs for Calculations / **Definitions**

		Method 1[2]	Method 2[3]	Definitions
MSg(sc)	=	23.74%	23.74%	market share of gas ovens that are self-cleaning
Rg(sc std)	=	0.830	0.830	ratio of self-cleaning gas oven cooking energy to stnd gas oven cooking energy
Rg(ct std)	=	0.872	0.875	ratio of gas cooktop cooking energy to stnd gas oven cooking energy
Egs	=	0.459	0.459	typical self-cleaning energy consumption per cycle
Sg	=	7	4	number of self-clean cycles per year
Oo	=	1.607	1.607	annual useful cooking energy output for gas ovens (old DOE test procedure)
Oct	=	9.475	9.475	annual useful cooking energy output for gas cooktops (old DOE test procedure)
EFFgo(sc)	=	7.1%	7.13%	cooking eff of the baseline self-cleaning gas oven
EFFgo(std)	=	5.9%	5.92%	cooking eff of the baseline standard gas oven
EFFg(ct)	=	39.9%	39.9%	cooking eff of the baseline gas cooktop

ELECTRIC

Annual Energy Use (kWh/yr)

		Method 1[2]	Method 2[3]
Elec Cooking, DATA	=	605.1	470.9
Elec Cooking, CALCULATED	=	578.2	461.1
Elec Oven	=	293.4	236.3
Elec Oven, Self-Cleaning	=	315.9	229.3
Elec Cooktop	=	272.2	228.7

ANNUAL USEFUL COOKING ENERGY OUTPUT

		Method 1[2]	Method 2[3]	
		kWh/yr	*kWh/yr*	*kBtu*
Standard Oven	=	35.5	28.6	97.6
Cooktop	=	209.4	168.6	575.7

Inputs for Calculations / **Definitions**

		Method 1[2]	Method 2[3]	Definitions
MSe(sc)	=	55.6%	55.6%	market share of elec ovens that are self-cleaning
Re(sc std)	=	0.871	0.877	ratio of self-cleaning elec oven cooking energy to stnd elec oven cooking energy
Re(ct std)	=	0.928	0.968	ratio of elec cooktop cooking energy to stnd elec oven cooking energy
Ees	=	5.5	5.5	typical self-cleaning energy consumption per cycle
Se	=	11	4	number of self-clean cycles per year
Oo(DOE)	=	47.1	47.1	annual useful cooking energy output for elec ovens (old DOE test procedure)
Oct(DOE)	=	277.7	277.7	annual useful cooking energy output for elec cooktops (old DOE test procedure)
EFFeo(sc)	=	13.9%	13.79%	cooking eff of the baseline self-cleaning elec oven
EFFeo(std)	=	12.1%	12.1%	cooking eff of the baseline standard elec oven
EFFe(ct)	=	77%	73.7%	cooking eff of the baseline elec cooktop

Notes **(1)** All output values calculated in accordance with the procedure shown in Appendix A, section A.1

(2) Method 1: Calculation Method for determining the Annnual Useful Cooking Energy Output for the DOE Proposed Test Procedure; number of self-clean cycles based on Existing DOE test procedure; baseline cooktop and oven cooking efficiencies based on data for DOE's Notice of Proposed Rulemaking (March 4, 1994).

(3) Method 2: Calculation Method for determining the Annnual Useful Cooking Energy Output using more recent field usage data from Table A.5; number of self-clean cycles based on 1994 Gas Research Institute Topical Report (GRI-94/0195); baseline cooktop and oven cooking efficiencies set equal to those values reported in Chapter 1 of this Report.

(4) Data are listed without pilot,e.g 29.5 Therms = 63.2 (usage w/pilot) - 33.7 (pilot)

Table A.7 Summary of Annual Useful Cooking Energy Outputs

	Annual Useful Cooking Energy Output		
	DOE Existing Test Procedure[7]	**DOE Proposed Test Procedure**[8]	**Recent, field usage data**[9]
GAS (kBtu/yr)			
Cooktops	947.5	732.5	527.6
Oven, standard	160.7	124.2	88.8
Oven, self-clean	160.7	124.2	88.8
ELECTRIC (kWh/yr)			
Cooktop, smooth	277.7	209.4	173.1
Cooktop, coil	277.7	209.4	173.1
Oven, standard	47.1	35.5	29.3
Oven, self-clean	47.1	35.5	29.3
Microwave Oven	34.2	77.3	79.8

A.3 MANUFACTURER COST DATA FOR KITCHEN RANGES AND OVENS

The following tables show the total manufacturing costs (1990$) for several design options for nine product classes of kitchen ranges and ovens. The total incremental manufacturing cost is disaggregated into five subcategories: materials (which includes purchased parts), labor, tooling/equipment, shipping/packaging, and indirect. Indirect costs include expenses such as general and administrative costs, research and development, rent, utility costs, and certification tests and fees. There are no indirect costs for microwave ovens. The disaggregated incremental costs for each design option are per unit produced and are not cumulative. The total costs at each design level are cumulative. The estimated uncertainty (at a 95% confidence level) for total incremental costs are provided for each design option. For most of the design options, the estimated uncertainty represents the range of values that were used in determining the incremental cost.

[7] Existing DOE Test Procedure, 10 CFR, Part 430, Subpart B, Appendix I, April, 1979.

[8] Proposed DOE Test Procedure, FR 60(56) pp 15330-15363, March, 1995.

[9] For electric and gas cooktops and oven, the annual useful cooking energy output values based on "recent, field usage data" in Table A.7 are not exactly equal to those being presented in Table A.6. This is because the values reported in Table A.7 are based on less recent cooktop and oven cooking efficiencies than were used in the calculations for Table A.6. The resulting errors casue minor changes in the life-cycle costs (no greater than 1%) and payback periods (2 to 3%) presented in Volume 2, Chapter 4 of this TSD.

Table A.8 Total Manufacturing Costs for Kitchen Ranges and Ovens (by Design Options)

Electric Cooktop, Coil Element

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1	0	Baseline: Coil Element	41.44	6.91	0.00	0.00	20.72	-	69.06	30%
2,3	1	0 + Imp Contact Conductance	2.28	0.00	0.00	0.00	0.00	2.28	71.34	35%
4,5	2	1 + Reflective Surfaces	0.00	2.60	0.10	0.00	0.34	3.03	74.37	55%

Electric Cooktop, Smooth Element

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline: Solid Disk Element	55.88	8.31	0.00	0.00	24.94	-	89.14	5%
	1	0 + Halogen Lamp Element	99.59	16.60	0.00	0.00	49.80	165.98	255.12	10%
5	2	0 + Induction Element	168.96	28.16	0.00	0.00	84.48	281.60	370.74	50%
	3	0 + Radiant Element	28.89	4.81	0.00	0.00	14.44	48.14	137.28	55%

Gas Cooktop

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline: Conventional	53.45	8.91	0.00	0.00	26.73	-	89.09	10%
1,2	1	0 + Electronic Ignition	12.06	0.00	0.00	0.00	0.00	12.06	101.15	5%
3,4	2	1 + Sealed Burners	20.00	0.00	0.00	0.00	0.00	20.00	121.15	20%
	3	2 + Reflective Surfaces	4.20	0.00	0.45	0.00	1.49	6.14	127.29	55%
5	4	3 + Thermostatic Burner	16.80	0.00	0.05	0.00	0.08	16.93	144.22	20%

Electric Oven, not Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline	87.70	14.62	0.00	0.00	43.85	-	146.17	20%
1	1	0 + Reduced Vent Rate	1.56	0.00	0.05	0.00	0.02	1.63	147.80	90%
2	2	1 + Improved Insulation	2.90	0.20	0.00	0.00	0.11	3.21	151.01	50%
3	3	2 + Improved Door Seals	3.69	0.00	0.00	0.00	0.00	3.69	154.70	25%
4	4	3 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	217.20	50%
	5	4 + Oven Separator	9.00	2.22	0.28	0.08	0.17	11.75	228.95	50%
	6	5 + Forced Convection	39.61	0.00	0.00	0.00	0.00	39.61	268.56	50%
5	7	6 + Reduced Cond. Losses	2.63	0.00	0.56	0.00	0.36	3.55	272.11	55%

Electric Oven, Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3	0	Baseline	111.09	18.52	0.00	0.00	55.55	-	185.15	5%
4	1	0 + Bi-Radiant Oven	37.50	6.25	0.00	0.00	18.75	62.50	247.65	50%
	2	1 + Oven Separator	9.00	2.22	0.56	0.08	0.34	12.20	259.85	45%
	3	2 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	264.22	55%
5	4	3 + Forced Convection	39.61	0.00	0.00	0.00	0.00	39.61	303.83	50%

Gas Oven, not Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
	0	Baseline	91.98	15.36	0.00	0.00	47.46	-	154.80	25%
1,2	1	0 + Electric Glo-bar Ignition	12.06	0.00	0.00	0.00	0.05	12.06	166.86	5%
3	2	1 + Improved Insulation	3.33	0.10	0.00	0.00	0.15	3.58	170.44	45%
	3	2 + Improved Door Seals	1.08	0.00	0.00	0.00	0.00	1.08	171.52	25%
4	4	3 + Forced Convection	18.42	0.93	0.00	0.00	2.79	22.14	193.66	50%
	5	4 + Reduced Vent Rate	1.62	0.00	0.00	0.00	0.00	1.62	195.28	90%
5	6	5 + Oven Separator	20.00	5.78	2.29	0.00	0.20	28.26	223.54	90%
	7	6 + Reduced Cond. Losses	2.63	0.00	0.61	0.00	0.39	3.63	227.17	55%
	8	0 + Electronic Spark Ignition	15.00	0.00	0.00	0.00	0.00	15.00	169.80	5%

Gas Oven, Self-Cleaning

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Ind. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline	132.15	22.03	0.00	0.00	66.08	-	220.26	10%
	1	0 + Forced Convection	6.61	1.10	0.00	0.00	3.30	11.01	231.27	50%
	2	1 + Reduced Cond. Losses	2.63	0.00	1.07	0.00	0.67	4.37	235.64	55%
	3	2 + Improved Door Seals	1.11	0.00	0.00	0.00	0.11	1.22	236.86	25%
5	4	3 + Oven Separator	29.00	7.62	8.90	0.00	0.45	45.97	282.83	90%

Microwave Ovens

Energy Efficiency Level	Design No.	Design Options	Mat. Cost	Labor Cost	Tool. Cost	Ship. Cost	Total Incr.	Total Cost	Uncert
1,2,3,4	0	Baseline	-	-	-	-	-	120.00	20%
	1	0 + Eff. Power Source	8.68	0.00	0.00	0.00	8.68	128.68	20%
	2	1 + Eff. Fan	9.27	0.00	0.00	0.00	9.27	137.95	20%
	3	2 + Improved Magnetron	14.58	0.00	0.00	0.00	14.58	152.53	20%
5	4	3 + Reflective Surfaces	18.58	0.00	0.00	0.00	18.58	171.11	20%

REFERENCES

1. U.S. Office of the Federal Register. 1978. 43 FR 20120, May 10, 1978.

2. U.S. Office of the Federal Register. 1979. 44 FR 22418, April 13, 1979.

3. U.S. Office of the Federal Register. 1995a. *Test Procedures for Water Heaters; Kitchen Ranges, Ovens, and Microwave Ovens; and Clothes Washers; and Reporting Requirements for Clothes Washers, Clothes Dryers and Dishwashers; Proposed Rule*. FR 60(56), March 23, 1995, pp 15330-15363.

4. U.S. Office of the Federal Register. 1995a. *Op. cit.*

5. U.S. Department of Energy. 1993. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Room Air Conditioners, Water Heaters, Direct Heating Equipment, Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts, and Television Sets. Volume 2: Fluorescent Lamp Ballasts, Television Sets, Room Air Conditioners, & Kitchen Ranges and Ovens*. Washington, DC, DOE/EE-0009, Vol. 2 of 3.

6. W. Hamilton. 1990. *Letter to Michael McCabe, DOE*, Association of Home Appliance Manufacturers, March 10, 1990.

7. U.S. Office of the Federal Register. 1995b. *Code of Federal Regulations, Title 10, Energy. Part 430, Subpart B, Appendix I: Uniform Test Method for Measuring the Energy Consumption of Cooking Tops, Conventional Ovens, Microwave Ovens, and Microwave/Conventional Ranges.* Washington, DC.

8. *Ibid.*

9. *Ibid.*

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11. U.S. Office of the Federal Register. 1995b. *Op. cit.*

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13. *Ibid.*

14. Gas Research Institute (GRI). 1994. *Topical Report: Technical Input to NAECA Rulemaking for Gas-Fired Ranges.* Prepared by Battelle, Columbus, OH, American Gas Associaiton Laboratories, Cleveland, OH, and Arthur D. Little, Cambridge, MA for Gas Appliance Technology Center, Chicago, IL. GRI-94/0195. p 8-2.

15. U.S. Office of the Federal Register. 1995a. *Op. cit.*

16. U.S. Office of the Federal Register. 1995b. *Op. cit.*

17. U.S. Department of Energy. 1993. *Op. cit.*

efficiency levels 1 through 5 for conventional ovens are summarized in Tables 7.6 through 7.10, and energy efficiency levels 1 through 5 for microwave ovens are summarized in Tables 7.11 through 7.15.

7.2.1 Sulfur and Nitrogen Oxide Emissions

Cooktops

Sulfur dioxide emissions would be decreased by a cumulative total of up to 67 kt (73,000 short tons) between 1998 and 2030 in the level 5 scenario. In the year 2000, decreases in SO_2 (due to proposed energy efficiency levels) will represent about .02% of SO_2 estimated to come from residential emissions in that year. In the year 2030, decreases in SO_2 will represent about .1% of SO_2 estimated to come from residential emissions in that year. Because of provisions in the Clean Air Act Amendments (Pub. L. 101-549, November 15, 1990), the possible reductions of SO_2 that are caused by efficiency levels can be earned as credits by the utility realizing the reductions. To the extent SO_2 credits are used for future emissions, the net effect on SO_2 emissions from efficiency levels would be only a postponement of those SO_2 emissions.

Level 5 design changes to cooktops would result in an estimated decrease in NO_x emissions of 65 kt (72,000 short tons) between 1998 and 2030. NO_x decreases would represent .47% and 2% of the NO_x emissions estimated to come from residential emissions in the years 2000 and 2030, respectively.

Conventional Ovens

Sulfur dioxide emissions would be decreased by a cumulative total of up to 241 kt (266,000 short tons) between 1998 and 2030 in the level 5 scenario. In the year 2000, decreases in SO_2 will represent about 0.05% of the SO_2 emissions estimated to come from residential emissions in that year. In the year 2030, decreases in SO_2 emissions will represent about 0.45% of the SO_2 emissions estimated to come from residential emissions in that year. As discussed above, the possible reductions of SO_2 emissions caused by efficiency levels can be earned as credits. To the extent credits are used for future emissions, the efficiency levels' net effect on those SO_2 emissions would be only a postponement.

Level 5 design changes to conventional ovens would result in an estimated decrease in NO_x emissions of 239 kt (263 short tons) between 1998 and 2030. NO_x decreases would represent .05% and .41% of the NO_x emissions estimated to come from residential emissions in the years 2000 and 2030, respectively.

Microwave Ovens

Sulfur dioxide emissions would be decreased by a cumulative total of up to 53 kt (58,000 short tons) between 1998 and 2030 in the level 5 scenario. In the year 2000, decreases in SO_2 will represent about .02% of the SO_2 emissions estimated to come from residential emissions in that year. In the year 2030, decreases in SO_2 emissions will represent about .08% of the SO_2 emissions estimated to come from residential emissions in that year. As discussed above, the possible reductions of SO_2 emissions caused by energy efficiency levels can be earned as credits. To the extent credits are used for future emissions, the efficiency levels' net effect on those SO_2 emissions would be only a postponement.

Level 5 design changes to microwave ovens would result in an estimated decrease in NO_x emissions of 48 kt (53,000 short tons) between 1998 and 2030. NO_x decreases would represent .02% and .07% of the NO_x emissions estimated to come from residential emissions in the years 2000 and 2030, respectively.

7.2.2 Carbon Dioxide Emissions

Cooktops

The cumulative reduction in CO_2 emissions from level 5 design changes is 36 Mt (39,000,000 short tons) of CO_2. For the year 2000, the estimated CO_2 reduction is .16 Mt (170,000 short tons) of CO_2 or about .01% of estimated U.S. total residential CO_2 emissions in 2000. For the year 2030, the estimated CO_2 reduction is 1.47 Mt (1,620,000 short tons) of CO_2, or about .09% of estimated U.S. total residential CO_2 emissions in 2030.

Conventional Ovens

The cumulative reduction in CO_2 emissions from level 5 design changes is 133 Mt (147,000,000 short tons) of CO_2. For the year 2000, the estimated CO_2 reduction is .52 Mt (570,000 short tons) of CO_2 or about .04% of estimated U.S. total residential CO_2 emissions in 2000. For the year 2030, the estimated CO_2 reduction is 6.15 Mt (6,770,000 short tons) of CO_2, or about .38% of estimated U.S. total residential CO_2 emissions in 2030.

Microwave Ovens

The cumulative reduction in CO_2 emissions from level 5 design changes is 25 Mt (28,000,000 short tons) of CO_2. For the year 2000, the estimated CO_2 reduction is .16 Mt (170,000 short tons) of CO_2 or about .01% of estimated U.S. total residential CO_2 emissions in 2000. For the year 2030, the estimated CO_2 reduction is 1.02 Mt (1,120,000 short tons) of CO_2, or about .06% of estimated U.S. total residential CO_2 emissions in 2030.

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 0 (short tons): 0 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 0 (short tons): 0 000

CO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 0 (short tons): 0 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.14	0.16	-0.01	-0.01	0.13	0.14	0.00
2005	0.51	0.56	0.00	0.00	0.51	0.56	0.02
2010	0.63	0.69	0.00	0.00	0.63	0.69	0.02
2015	0.52	0.58	-0.01	-0.01	0.51	0.56	0.02
2020	0.26	0.28	-0.01	-0.01	0.24	0.27	0.01
2025	0.04	0.05	0.00	0.00	0.04	0.05	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 11 (short tons): 12 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.11	0.12	-0.01	-0.01	0.10	0.11	0.00
2005	0.41	0.45	-0.01	-0.01	0.40	0.44	0.01
2010	0.55	0.60	-0.01	-0.01	0.53	0.59	0.02
2015	0.48	0.53	-0.02	-0.02	0.47	0.51	0.02
2020	0.26	0.28	-0.01	-0.02	0.24	0.27	0.01
2025	0.05	0.05	0.00	0.00	0.04	0.05	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 9 (short tons): 10 000

CO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.04	0.04	-0.01	-0.01	0.03	0.04	0.00
2005	0.17	0.19	-0.01	-0.01	0.16	0.17	0.01
2010	0.24	0.27	-0.01	-0.02	0.23	0.25	0.02
2015	0.25	0.27	-0.02	-0.02	0.23	0.25	0.02
2020	0.15	0.17	-0.02	-0.02	0.14	0.15	0.01
2025	0.03	0.03	0.00	-0.01	0.03	0.03	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 4 (short tons): 5 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.11	0.13	-0.01	-0.01	0.10	0.11	0.00
2005	0.41	0.46	-0.04	-0.04	0.37	0.41	0.01
2010	0.50	0.56	-0.05	-0.06	0.45	0.50	0.02
2015	0.37	0.41	-0.09	-0.10	0.28	0.31	0.01
2020	0.15	0.16	-0.08	-0.09	0.07	0.07	0.00
2025	-0.04	-0.05	-0.07	-0.07	-0.11	-0.12	-0.01
2030	-0.08	-0.09	-0.08	-0.09	-0.16	-0.18	-0.01

Cumulative SO_2 reduction (kt): 5 (short tons): 6 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.09	0.09	0.02	0.02	0.10	0.11	0.00
2005	0.33	0.37	0.06	0.07	0.40	0.44	0.01
2010	0.44	0.48	0.13	0.14	0.56	0.62	0.02
2015	0.34	0.38	0.19	0.21	0.53	0.58	0.02
2020	0.15	0.16	0.21	0.24	0.36	0.40	0.02
2025	-0.05	-0.05	0.23	0.26	0.19	0.21	0.01
2030	-0.10	-0.11	0.25	0.27	0.15	0.17	0.01

Cumulative NOxreduction (kt): 11 (short tons): 12 000

CO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.03	0.04	0.02	0.02	0.05	0.05	0.00
2005	0.14	0.15	0.06	0.07	0.20	0.22	0.02
2010	0.19	0.21	0.13	0.14	0.32	0.35	0.02
2015	0.18	0.19	0.19	0.20	0.36	0.40	0.03
2020	0.09	0.10	0.22	0.24	0.30	0.34	0.02
2025	-0.03	-0.03	0.24	0.26	0.21	0.23	0.01
2030	-0.08	-0.09	0.25	0.28	0.17	0.19	0.01

Cumulative CO_2 reduction (Mt): 8 (short tons): 8 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.17	0.19	-0.01	-0.01	0.16	0.17	0.00
2005	0.61	0.67	-0.04	-0.04	0.57	0.63	0.02
2010	0.80	0.88	-0.05	-0.06	0.74	0.82	0.03
2015	0.73	0.80	-0.09	-0.10	0.63	0.70	0.03
2020	0.45	0.49	-0.08	-0.09	0.37	0.40	0.02
2025	0.20	0.22	-0.09	-0.10	0.10	0.11	0.01
2030	0.12	0.13	-0.08	-0.09	0.04	0.04	0.00

Cumulative SO_2 reduction (kt): 13 (short tons): 14 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.13	0.14	0.01	0.01	0.14	0.15	0.01
2005	0.49	0.54	0.06	0.07	0.55	0.61	0.02
2010	0.69	0.76	0.11	0.12	0.80	0.88	0.03
2015	0.67	0.74	0.16	0.18	0.84	0.92	0.03
2020	0.45	0.49	0.19	0.21	0.64	0.70	0.03
2025	0.22	0.24	0.20	0.22	0.42	0.46	0.02
2030	0.14	0.16	0.22	0.24	0.36	0.40	0.02

Cumulative NOxreduction (kt): 18 (short tons): 20

CO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.05	0.05	0.01	0.01	0.06	0.07	0.00
2005	0.20	0.22	0.06	0.06	0.26	0.29	0.02
2010	0.31	0.34	0.11	0.12	0.41	0.46	0.03
2015	0.34	0.38	0.16	0.18	0.51	0.56	0.04
2020	0.26	0.29	0.19	0.21	0.46	0.50	0.03
2025	0.15	0.17	0.20	0.22	0.35	0.39	0.02
2030	0.12	0.13	0.22	0.24	0.34	0.37	0.02

Cumulative CO_2 reduction (Mt): 11 (short tons): 12 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.57	0.63	-0.01	-0.01	0.56	0.61	0.02
2005	1.92	2.12	-0.04	-0.04	1.88	2.07	0.06
2010	2.86	3.15	-0.05	-0.06	2.80	3.09	0.10
2015	3.10	3.42	-0.11	-0.12	3.00	3.30	0.12
2020	2.57	2.83	-0.09	-0.10	2.47	2.72	0.12
2025	1.89	2.08	-0.09	-0.10	1.79	1.98	0.11
2030	1.46	1.61	-0.08	-0.09	1.38	1.52	0.10

Cumulative SO_2 reduction (kt): 67 (short tons): 73 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.42	0.47	0.00	0.00	0.42	0.47	0.02
2005	1.55	1.70	-0.01	-0.01	1.54	1.70	0.06
2010	2.48	2.74	0.00	0.00	2.48	2.73	0.09
2015	2.88	3.17	-0.01	-0.01	2.87	3.16	0.12
2020	2.57	2.83	0.00	0.00	2.56	2.83	0.11
2025	2.07	2.28	0.01	0.01	2.07	2.29	0.10
2030	1.79	1.97	0.02	0.02	1.81	1.99	0.10

Cumulative NOxreduction (kt): 65 (short tons): 72 000

CO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.16	0.18	0.00	0.00	0.16	0.17	0.01
2005	0.63	0.70	-0.01	-0.01	0.62	0.68	0.05
2010	1.10	1.21	-0.01	-0.01	1.09	1.20	0.08
2015	1.48	1.63	-0.02	-0.02	1.46	1.60	0.10
2020	1.52	1.67	-0.01	-0.01	1.51	1.66	0.10
2025	1.44	1.59	0.00	0.00	1.44	1.58	0.09
2030	1.46	1.61	0.01	0.01	1.47	1.62	0.09

Cumulative CO_2 reduction (Mt): 36 (short tons): 39 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.09	0.09	0.00	0.00	0.09	0.09	0.00
2005	0.29	0.32	0.00	0.00	0.29	0.32	0.01
2010	0.48	0.53	0.00	0.00	0.48	0.53	0.02
2015	0.56	0.61	-0.01	-0.01	0.54	0.60	0.02
2020	0.49	0.54	-0.01	-0.01	0.47	0.52	0.02
2025	0.39	0.43	0.00	0.00	0.39	0.43	0.02
2030	0.31	0.34	-0.01	-0.01	0.29	0.32	0.02

Cumulative SO_2 reduction (kt): 12 (short tons): 13 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.06	0.07	0.00	0.00	0.06	0.07	0.00
2005	0.23	0.26	0.00	0.00	0.23	0.25	0.01
2010	0.42	0.46	-0.01	-0.01	0.41	0.45	0.02
2015	0.52	0.57	-0.02	-0.02	0.50	0.55	0.02
2020	0.49	0.54	-0.02	-0.03	0.46	0.51	0.02
2025	0.43	0.48	-0.02	-0.02	0.41	0.46	0.02
2030	0.38	0.41	-0.02	-0.03	0.35	0.39	0.02

Cumulative NOxreduction (kt): 11 (short tons): 13 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.02	0.03	0.00	0.00	0.02	0.03	0.00
2005	0.10	0.11	0.00	-0.01	0.09	0.10	0.01
2010	0.19	0.20	-0.01	-0.01	0.18	0.19	0.01
2015	0.26	0.29	-0.02	-0.02	0.24	0.27	0.02
2020	0.29	0.32	-0.03	-0.03	0.26	0.29	0.02
2025	0.30	0.33	-0.02	-0.02	0.28	0.31	0.02
2030	0.31	0.34	-0.03	-0.03	0.28	0.31	0.02

Cumulative CO_2 reduction (Mt): 6 (short tons): 7 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.17	0.19	-0.01	-0.01	0.16	0.17	0.00
2005	0.63	0.70	0.00	0.00	0.63	0.70	0.02
2010	0.97	1.07	-0.01	-0.01	0.95	1.05	0.03
2015	1.15	1.26	-0.03	-0.03	1.12	1.23	0.05
2020	1.00	1.10	-0.03	-0.03	0.97	1.07	0.05
2025	0.81	0.89	-0.01	-0.01	0.80	0.88	0.05
2030	0.63	0.69	-0.01	-0.01	0.61	0.68	0.04

Cumulative SO_2 reduction (kt): 25 (short tons): 28 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.13	0.14	-0.01	-0.01	0.12	0.13	0.00
2005	0.51	0.56	-0.01	-0.01	0.50	0.55	0.02
2010	0.84	0.93	-0.03	-0.04	0.81	0.89	0.03
2015	1.06	1.17	-0.04	-0.05	1.02	1.12	0.04
2020	1.00	1.10	-0.05	-0.06	0.95	1.04	0.04
2025	0.89	0.98	-0.05	-0.06	0.84	0.92	0.04
2030	0.77	0.85	-0.05	-0.06	0.72	0.79	0.04

Cumulative NOxreduction (kt): 23 (short tons): 26 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.05	0.05	-0.01	-0.01	0.04	0.04	0.00
2005	0.21	0.23	-0.01	-0.02	0.19	0.21	0.01
2010	0.37	0.41	-0.04	-0.04	0.33	0.37	0.02
2015	0.55	0.60	-0.05	-0.05	0.50	0.55	0.03
2020	0.59	0.65	-0.06	-0.06	0.53	0.59	0.04
2025	0.62	0.68	-0.05	-0.06	0.56	0.62	0.04
2030	0.63	0.69	-0.05	-0.06	0.57	0.63	0.04

Cumulative CO_2 reduction (Mt): 13 (short tons): 14 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.09	0.09	-0.03	-0.03	0.06	0.06	0.00
2005	0.27	0.29	-0.07	-0.07	0.20	0.22	0.01
2010	0.46	0.51	-0.09	-0.10	0.37	0.41	0.01
2015	0.56	0.61	-0.15	-0.16	0.41	0.45	0.02
2020	0.50	0.55	-0.16	-0.18	0.34	0.37	0.02
2025	0.40	0.45	-0.16	-0.18	0.24	0.27	0.01
2030	0.31	0.35	-0.15	-0.16	0.17	0.18	0.01

Cumulative SO_2 reduction (kt): 9 (short tons): 10 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.06	0.07	0.02	0.02	0.08	0.09	0.00
2005	0.22	0.24	0.11	0.12	0.32	0.36	0.01
2010	0.40	0.44	0.20	0.23	0.61	0.67	0.02
2015	0.52	0.57	0.29	0.31	0.80	0.88	0.03
2020	0.50	0.55	0.31	0.34	0.81	0.89	0.04
2025	0.44	0.49	0.33	0.36	0.77	0.85	0.04
2030	0.39	0.42	0.34	0.38	0.73	0.80	0.04

Cumulative NOxreduction (kt): 19 (short tons): 21 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.02	0.03	0.02	0.02	0.04	0.05	0.00
2005	0.09	0.10	0.11	0.12	0.19	0.21	0.01
2010	0.18	0.20	0.20	0.23	0.38	0.42	0.03
2015	0.26	0.29	0.28	0.31	0.55	0.61	0.04
2020	0.30	0.33	0.31	0.34	0.61	0.67	0.04
2025	0.31	0.34	0.32	0.36	0.63	0.70	0.04
2030	0.31	0.35	0.35	0.38	0.66	0.73	0.04

Cumulative CO_2 reduction (Mt): 14 (short tons): 15 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	1.94	2.14	-0.04	-0.04	1.90	2.09	0.05
2005	6.25	6.89	-0.11	-0.12	6.15	6.77	0.20
2010	9.63	10.61	-0.19	-0.21	9.44	10.40	0.33
2015	11.26	12.41	-0.27	-0.30	11.00	12.12	0.46
2020	10.04	11.06	-0.30	-0.33	9.74	10.73	0.47
2025	8.03	8.85	-0.30	-0.33	7.74	8.52	0.46
2030	6.31	6.95	-0.30	-0.33	6.01	6.63	0.44

Cumulative SO_2 reduction (kt): 247 (short tons): 273 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	1.45	1.59	-0.03	-0.04	1.41	1.55	0.05
2005	5.03	5.55	-0.10	-0.11	4.93	5.43	0.18
2010	8.36	9.22	-0.19	-0.21	8.18	9.01	0.31
2015	10.44	11.51	-0.27	-0.30	10.17	11.21	0.42
2020	10.04	11.06	-0.31	-0.34	9.72	10.72	0.43
2025	8.80	9.69	-0.33	-0.36	8.47	9.34	0.41
2030	7.76	8.55	-0.33	-0.37	7.42	8.18	0.40

Cumulative NOxreduction (kt): 236 (short tons): 260 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.54	0.60	-0.04	-0.04	0.50	0.55	0.04
2005	2.06	2.27	-0.12	-0.13	1.94	2.14	0.15
2010	3.69	4.07	-0.21	-0.24	3.47	3.83	0.25
2015	5.36	5.90	-0.32	-0.35	5.04	5.56	0.35
2020	5.94	6.54	-0.36	-0.39	5.58	6.15	0.37
2025	6.12	6.75	-0.37	-0.41	5.75	6.34	0.37
2030	6.32	6.96	-0.38	-0.42	5.93	6.54	0.37

Cumulative CO_2 reduction (Mt): 129 (short tons): 142 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	1.91	2.11	-0.04	-0.04	1.87	2.06	0.05
2005	6.16	6.79	-0.15	-0.16	6.01	6.62	0.19
2010	9.50	10.47	-0.24	-0.27	9.26	10.20	0.33
2015	11.11	12.25	-0.36	-0.40	10.75	11.85	0.45
2020	9.90	10.91	-0.40	-0.44	9.50	10.47	0.46
2025	7.94	8.75	-0.40	-0.44	7.53	8.30	0.45
2030	6.23	6.87	-0.39	-0.43	5.84	6.44	0.43

Cumulative SO_2 reduction (kt): 241 (short tons): 266 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	1.42	1.57	-0.01	-0.01	1.42	1.56	0.05
2005	4.95	5.46	-0.02	-0.02	4.94	5.44	0.18
2010	8.26	9.10	-0.01	-0.02	8.24	9.08	0.31
2015	10.30	11.35	-0.03	-0.04	10.27	11.32	0.42
2020	9.90	10.91	-0.05	-0.06	9.85	10.85	0.44
2025	8.69	9.58	-0.05	-0.06	8.64	9.52	0.42
2030	7.66	8.44	-0.05	-0.05	7.61	8.39	0.41

Cumulative NOxreduction (kt): 239 (short tons): 263 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.53	0.59	-0.01	-0.01	0.52	0.57	0.04
2005	2.03	2.23	-0.03	-0.04	1.99	2.20	0.15
2010	3.64	4.01	-0.04	-0.04	3.60	3.97	0.26
2015	5.29	5.82	-0.07	-0.08	5.21	5.74	0.36
2020	5.86	6.46	-0.10	-0.11	5.76	6.35	0.38
2025	6.05	6.67	-0.10	-0.11	5.95	6.56	0.38
2030	6.24	6.87	-0.09	-0.10	6.15	6.77	0.38

Cumulative CO_2 reduction (Mt): 133 (short tons): 147 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 0 (short tons): 0 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 0 (short tons): 0 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 0 (short tons): 0 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 0 (short tons): 0 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 0 (short tons): 0 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 0 (short tons): 0 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 0 (short tons): 0 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 0 (short tons): 0 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 0 (short tons): 0 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative SO_2 reduction (kt): 0 (short tons): 0 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative NOxreduction (kt): 0 (short tons): 0 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cumulative CO_2 reduction (Mt): 0 (short tons): 0 000 000

SO_2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.63	0.69	-0.01	-0.01	0.61	0.68	0.02
2005	1.92	2.12	-0.03	-0.03	1.90	2.09	0.06
2010	2.42	2.66	-0.03	-0.03	2.39	2.63	0.08
2015	2.06	2.27	-0.04	-0.04	2.02	2.22	0.08
2020	1.74	1.92	-0.04	-0.04	1.70	1.88	0.08
2025	1.41	1.56	-0.03	-0.03	1.38	1.53	0.08
2030	1.11	1.22	-0.04	-0.04	1.06	1.17	0.08

Cumulative SO_2 reduction (kt): 53 (short tons): 58 000

NOx

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	kt	thousand short tons	kt	thousand short tons	kt	thousand short tons	
2000	0.47	0.52	-0.01	-0.02	0.45	0.50	0.02
2005	1.55	1.70	-0.05	-0.05	1.50	1.65	0.06
2010	2.10	2.31	-0.06	-0.07	2.04	2.25	0.08
2015	1.91	2.10	-0.07	-0.07	1.84	2.03	0.08
2020	1.74	1.92	-0.08	-0.08	1.67	1.84	0.07
2025	1.55	1.70	-0.07	-0.08	1.47	1.62	0.07
2030	1.36	1.50	-0.08	-0.09	1.28	1.41	0.07

Cumulative NOxreduction (kt): 48 (short tons): 53 000

CO2

Year	Abated from Power Plants		Abated from In House		Total Reduction in Emissions		Reduction as a % of Total Residential Emissions
	Mt	million short tons	Mt	million short tons	Mt	million short tons	
2000	0.17	0.19	-0.02	-0.02	0.16	0.17	0.01
2005	0.63	0.70	-0.05	-0.06	0.58	0.64	0.04
2010	0.93	1.02	-0.07	-0.07	0.86	0.95	0.06
2015	0.98	1.08	-0.07	-0.08	0.90	1.00	0.06
2020	1.03	1.14	-0.08	-0.09	0.95	1.04	0.06
2025	1.08	1.19	-0.08	-0.09	1.00	1.10	0.06
2030	1.11	1.22	-0.09	-0.10	1.02	1.12	0.06

Cumulative CO_2 reduction (Mt): 25 (short tons): 28 000 000

Peak demand changes from the energy efficiency levels for cooktops range from 0 to a decrease 0.04 GW in 2000, and from an increase of 0.02 in level 3 to a decrease of 0.41 GW in 2030. Capacity savings for cooktops range from 0 to a decrease of .05 GW in 2000, and from an increase of 0.03 in level 3 to a decrease of 0.49 GW in 2030. Peak demand reductions from the energy efficiency levels for ovens range from 0.01 to 0.15 GW in 2000, and from 0.09 to 1.75 GW in 2030. Capacity savings for ovens range from 0.01 to 0.18 GW in 2000, and from 0.10 to 2.10 GW in 2030. Peak demand reductions from the energy efficiency levels for microwaves range from 0 to 0.05 GW in 2000, and from 0 to 0.31 GW in 2030. Capacity savings for microwaves range from 0 to 0.06 GW in 2000, and from 0 to 0.37 GW in 2030.

Table 6.1 Avoided Cost Rate for Selected Years

AVOIDED COST RATES (1990$/MMBtu)				
Year	**Avoided Energy Cost Rate**	**Avoided CapacityCost Rate**	**Avoided Transmission and Distribution Cost Rate**	**Total Avoided Cost Rate**
2000	2.28	1.22	.39	3.88
2005	2.47	1.22	.4	4.09
2010	2.66	1.22	.42	4.29
2015	2.84	1.22	.43	4.49
2020	3.03	1.22	.44	4.70
2025	3.22	1.22	.46	4.90
2030	3.41	1.22	.47	5.10

Table 6.2 Peak Demand Reductions (GW) - Cooktops

		PEAK DEMAND SAVINGS (GW)				
Year	Peak Load	Level 1	Level 2	Level 3	Level 4	Level 5
2000	3.46	0.00	0.01	0.01	0.01	0.04
2001	3.48	0.00	0.02	0.02	0.02	0.07
2002	3.51	0.00	0.02	0.02	0.03	0.09
2003	3.53	0.00	0.03	0.03	0.04	0.12
2004	3.56	0.00	0.04	0.03	0.05	0.15
2005	3.58	0.00	0.05	0.04	0.05	0.17
2006	3.61	0.00	0.05	0.04	0.06	0.20
2007	3.63	0.00	0.06	0.05	0.07	0.23
2008	3.66	0.00	0.07	0.06	0.08	0.26
2009	3.68	0.00	0.07	0.05	0.08	0.28
2010	3.71	0.00	0.07	0.05	0.08	0.30
2011	3.73	0.00	0.07	0.05	0.09	0.32
2012	3.76	0.00	0.07	0.05	0.09	0.34
2013	3.78	0.00	0.07	0.05	0.09	0.36
2014	3.8	0.00	0.07	0.05	0.09	0.39
2015	3.83	0.00	0.07	0.05	0.09	0.40
2016	3.85	0.00	0.06	0.04	0.09	0.41
2017	3.87	0.00	0.06	0.04	0.09	0.42
2018	3.89	0.00	0.05	0.04	0.08	0.42
2019	3.92	0.00	0.05	0.03	0.08	0.42
2020	3.95	0.00	0.04	0.02	0.07	0.42
2021	3.97	0.00	0.04	0.02	0.06	0.42
2022	3.99	0.00	0.03	0.01	0.06	0.41
2023	4.02	0.00	0.02	0.00	0.05	0.41
2024	4.04	0.00	0.02	0.00	0.05	0.41
2025	4.07	0.00	0.01	-0.01	0.04	0.40
2026	4.1	0.00	0.00	-0.02	0.04	0.40
2027	4.13	0.00	0.00	-0.02	0.03	0.40
2028	4.16	0.00	0.00	-0.02	0.03	0.40
2029	4.19	0.00	0.00	-0.02	0.04	0.41
2030	4.22	0.00	0.00	-0.02	0.03	0.41

Table 6.3 Peak Demand Reductions (GW) - Ovens

		PEAK DEMAND SAVINGS (GW)				
Year	Peak Load	Level 1	Level 2	Level 3	Level 4	Level 5
2000	4.22	0.01	0.01	0.01	0.15	0.15
2001	4.26	0.01	0.02	0.01	0.23	0.23
2002	4.31	0.02	0.03	0.02	0.31	0.31
2003	4.35	0.02	0.04	0.02	0.39	0.39
2004	4.40	0.02	0.05	0.02	0.48	0.47
2005	4.46	0.03	0.06	0.02	0.57	0.56
2006	4.51	0.03	0.06	0.03	0.65	0.64
2007	4.56	0.04	0.07	0.04	0.74	0.73
2008	4.62	0.04	0.08	0.04	0.83	0.82
2009	4.68	0.05	0.09	0.04	0.92	0.90
2010	4.73	0.05	0.10	0.05	1.01	0.99
2011	4.77	0.05	0.11	0.05	1.10	1.09
2012	4.82	0.06	0.12	0.06	1.20	1.18
2013	4.86	0.06	0.13	0.06	1.29	1.28
2014	4.90	0.07	0.14	0.07	1.39	1.37
2015	4.94	0.07	0.15	0.07	1.47	1.45
2016	4.98	0.07	0.15	0.07	1.53	1.51
2017	5.02	0.08	0.16	0.08	1.58	1.55
2018	5.06	0.08	0.16	0.08	1.60	1.58
2019	5.11	0.08	0.16	0.08	1.62	1.60
2020	5.15	0.08	0.16	0.08	1.63	1.61
2021	5.19	0.08	0.16	0.08	1.64	1.62
2022	5.24	0.08	0.17	0.08	1.66	1.64
2023	5.28	0.08	0.17	0.08	1.68	1.66
2024	5.32	0.08	0.17	0.09	1.69	1.67
2025	5.37	0.08	0.17	0.09	1.70	1.68
2026	5.41	0.08	0.17	0.09	1.72	1.70
2027	5.46	0.08	0.17	0.09	1.73	1.71
2028	5.50	0.09	0.17	0.09	1.74	1.72
2029	5.55	0.09	0.18	0.09	1.76	1.73
2030	5.60	0.09	0.18	0.09	1.77	1.75

Table 6.4 Peak Demand Reductions (GW) - Microwaves

		PEAK DEMAND SAVINGS (GW)				
Year	Peak Load	Level 1	Level 2	Level 3	Level 4	Level 5
2000	2.99	0.00	0.00	0.00	0.00	0.05
2001	3.04	0.00	0.00	0.00	0.00	0.07
2002	3.09	0.00	0.00	0.00	0.00	0.10
2003	3.14	0.00	0.00	0.00	0.00	0.13
2004	3.19	0.00	0.00	0.00	0.00	0.15
2005	3.24	0.00	0.00	0.00	0.00	0.17
2006	3.29	0.00	0.00	0.00	0.00	0.20
2007	3.33	0.00	0.00	0.00	0.00	0.22
2008	3.37	0.00	0.00	0.00	0.00	0.24
2009	3.42	0.00	0.00	0.00	0.00	0.25
2010	3.46	0.00	0.00	0.00	0.00	0.25
2011	3.50	0.00	0.00	0.00	0.00	0.26
2012	3.54	0.00	0.00	0.00	0.00	0.26
2013	3.58	0.00	0.00	0.00	0.00	0.26
2014	3.62	0.00	0.00	0.00	0.00	0.26
2015	3.67	0.00	0.00	0.00	0.00	0.27
2016	3.71	0.00	0.00	0.00	0.00	0.27
2017	3.75	0.00	0.00	0.00	0.00	0.27
2018	3.79	0.00	0.00	0.00	0.00	0.28
2019	3.84	0.00	0.00	0.00	0.00	0.28
2020	3.88	0.00	0.00	0.00	0.00	0.28
2021	3.92	0.00	0.00	0.00	0.00	0.29
2022	3.96	0.00	0.00	0.00	0.00	0.29
2023	4.00	0.00	0.00	0.00	0.00	0.29
2024	4.05	0.00	0.00	0.00	0.00	0.29
2025	4.09	0.00	0.00	0.00	0.00	0.30
2026	4.13	0.00	0.00	0.00	0.00	0.30
2027	4.17	0.00	0.00	0.00	0.00	0.30
2028	4.22	0.00	0.00	0.00	0.00	0.31
2029	4.26	0.00	0.00	0.00	0.00	0.31
2030	4.30	0.00	0.00	0.00	0.00	0.31

Table 6.5 Capacity Savings (GW) - Cooktops

Year	CAPACITY SAVINGS (GW) Level 1	Level 2	Level 3	Level 4	Level 5
2000	0.00	0.01	0.01	0.02	0.05
2001	0.00	0.02	0.02	0.03	0.08
2002	0.00	0.03	0.02	0.04	0.11
2003	0.00	0.04	0.03	0.04	0.15
2004	0.00	0.05	0.04	0.06	0.17
2005	0.00	0.06	0.04	0.07	0.21
2006	0.00	0.06	0.05	0.07	0.24
2007	0.00	0.07	0.06	0.09	0.27
2008	0.00	0.08	0.07	0.10	0.31
2009	0.00	0.08	0.07	0.10	0.34
2010	0.00	0.08	0.06	0.10	0.36
2011	0.00	0.08	0.06	0.10	0.38
2012	0.00	0.08	0.06	0.11	0.41
2013	0.00	0.08	0.06	0.11	0.44
2014	0.00	0.08	0.06	0.11	0.46
2015	0.00	0.08	0.06	0.11	0.49
2016	0.00	0.07	0.05	0.11	0.5
2017	0.00	0.07	0.05	0.11	0.51
2018	0.00	0.07	0.04	0.10	0.51
2019	0.00	0.06	0.03	0.09	0.51
2020	0.00	0.05	0.03	0.09	0.5
2021	0.00	0.04	0.02	0.08	0.5
2022	0.00	0.04	0.01	0.07	0.5
2023	0.00	0.03	0.00	0.07	0.49
2024	0.00	0.02	-0.01	0.06	0.49
2025	0.00	0.01	-0.01	0.05	0.48
2026	0.00	0.01	-0.02	0.04	0.48
2027	0.00	0.00	-0.02	0.04	0.48
2028	0.00	0.00	-0.02	0.04	0.48
2029	0.00	0.00	-0.02	0.04	0.49
2030	0.00	0.00	-0.03	0.04	0.49

Table 6.6 Capacity Savings (GW) - Ovens

	CAPACITY SAVINGS (GW)				
Year	Level 1	Level 2	Level 3	Level 4	Level 5
2000	0.01	0.02	0.01	0.18	0.18
2001	0.02	0.03	0.02	0.28	0.27
2002	0.02	0.04	0.02	0.37	0.37
2003	0.02	0.05	0.02	0.47	0.46
2004	0.03	0.06	0.03	0.57	0.56
2005	0.03	0.07	0.03	0.68	0.67
2006	0.04	0.08	0.03	0.78	0.77
2007	0.04	0.09	0.04	0.89	0.87
2008	0.05	0.10	0.05	0.99	0.98
2009	0.06	0.11	0.05	1.10	1.08
2010	0.06	0.12	0.06	1.21	1.19
2011	0.07	0.13	0.06	1.32	1.30
2012	0.07	0.14	0.07	1.44	1.42
2013	0.08	0.16	0.07	1.55	1.53
2014	0.08	0.17	0.08	1.66	1.64
2015	0.09	0.18	0.09	1.76	1.74
2016	0.09	0.18	0.09	1.84	1.81
2017	0.09	0.19	0.09	1.89	1.87
2018	0.09	0.19	0.09	1.92	1.90
2019	0.09	0.20	0.09	1.94	1.92
2020	0.09	0.20	0.10	1.96	1.93
2021	0.09	0.20	0.10	1.97	1.95
2022	0.10	0.20	0.10	1.99	1.97
2023	0.10	0.20	0.10	2.01	1.99
2024	0.10	0.20	0.10	2.03	2.00
2025	0.10	0.21	0.10	2.04	2.02
2026	0.10	0.21	0.11	2.06	2.03
2027	0.10	0.21	0.11	2.07	2.05
2028	0.10	0.21	0.11	2.09	2.07
2029	0.10	0.21	0.11	2.11	2.08
2030	0.10	0.21	0.11	2.12	2.10

Table 6.7 Capacity Savings (GW) - Microwaves

	CAPACITY SAVINGS (GW)				
Year	Level 1	Level 2	Level 3	Level 4	Level 5
2000	0.00	0.00	0.00	0.00	0.06
2001	0.00	0.00	0.00	0.00	0.09
2002	0.00	0.00	0.00	0.00	0.12
2003	0.00	0.00	0.00	0.00	0.15
2004	0.00	0.00	0.00	0.00	0.18
2005	0.00	0.00	0.00	0.00	0.21
2006	0.00	0.00	0.00	0.00	0.23
2007	0.00	0.00	0.00	0.00	0.26
2008	0.00	0.00	0.00	0.00	0.28
2009	0.00	0.00	0.00	0.00	0.30
2010	0.00	0.00	0.00	0.00	0.30
2011	0.00	0.00	0.00	0.00	0.31
2012	0.00	0.00	0.00	0.00	0.31
2013	0.00	0.00	0.00	0.00	0.31
2014	0.00	0.00	0.00	0.00	0.32
2015	0.00	0.00	0.00	0.00	0.32
2016	0.00	0.00	0.00	0.00	0.32
2017	0.00	0.00	0.00	0.00	0.33
2018	0.00	0.00	0.00	0.00	0.33
2019	0.00	0.00	0.00	0.00	0.34
2020	0.00	0.00	0.00	0.00	0.34
2021	0.00	0.00	0.00	0.00	0.34
2022	0.00	0.00	0.00	0.00	0.35
2023	0.00	0.00	0.00	0.00	0.35
2024	0.00	0.00	0.00	0.00	0.35
2025	0.00	0.00	0.00	0.00	0.36
2026	0.00	0.00	0.00	0.00	0.36
2027	0.00	0.00	0.00	0.00	0.36
2028	0.00	0.00	0.00	0.00	0.37
2029	0.00	0.00	0.00	0.00	0.37
2030	0.00	0.00	0.00	0.00	0.37

6.4 REVENUE LOSSES

Appliance energy efficiency levels allow utilities to avoid the variable costs of generating electricity, but efficiency levels also reduce electricity sales. In a Public Utilities Commission rate case, the utility and the regulators agree on the revenue requirements and rates based on some estimate of future sales. If the effects of appliance efficiency levels are not included in this forecast, actual sales will be less than forecasted sales, which implies that the utility will not be able to recover some of the fixed costs that were included in the original revenue requirements calculation. This effect can be eliminated if electric utilities and regulators, when calculating rates, correctly forecast the impacts of appliance efficiency levels.

Utilities routinely petition regulators for changes in rates. In the course of such a petition the utility's forecasted sales can be adjusted to account for the appliance efficiency levels and hence eliminate these "lost" revenues. Those revenues lost as a result of time lags in regulation are not a true economic cost, but are a transfer payment from the utility to utility customers. The size of this transfer payment depends on regulatory behavior and on the net change in revenues, which is equal to the difference between sales reductions and avoided costs.

Since the magnitude of these losses is dependent on assumptions about regulatory behavior, and because this behavior is so varied among states, it is difficult to perform this calculation for the nation. An additional complication is that unanticipated sales growth from other sectors may compensate for the revenue shortfall. Two cases are presented here, one which assumes that regulators adjust the rates to reflect the reduced sales in five years, and one which assumes that they never adjust the rates. These cases also assume that there is no unanticipated compensating sales growth. These results are presented both on a year-by-year and a present-value basis.

It is possible that the regulators could adjust the rates in anticipation of the new efficiency levels, in which case there would be no revenue impact at all. It is also possible that the regulators would not grant rate relief for several years after the efficiency levels go into effect, which is approximated by the five-year-lag case. While it is unlikely that regulators would never adjust the rates to reflect the post-efficiency level sales forecast, this case is included as an absolute upper bound. Figures 6.1 to 6.3 show annual revenue losses and avoided costs over time and for all energy efficiency levels.

Tables 6.8 to 6.10 show utility revenue losses, assuming no regulatory adjustment. When this adjustment is made, rates will be increased over the base-case forecast, and utilities will cease to lose revenue.

Cumulative changes in net revenues for cooktops range from 0 to 1.04 billion $1990. Cumulative changes in net revenues for ovens range from 0.19 to 3.88 billion $1990. Cumulative net revenue losses for microwaves range from 0 to 0.79 billion $1990.

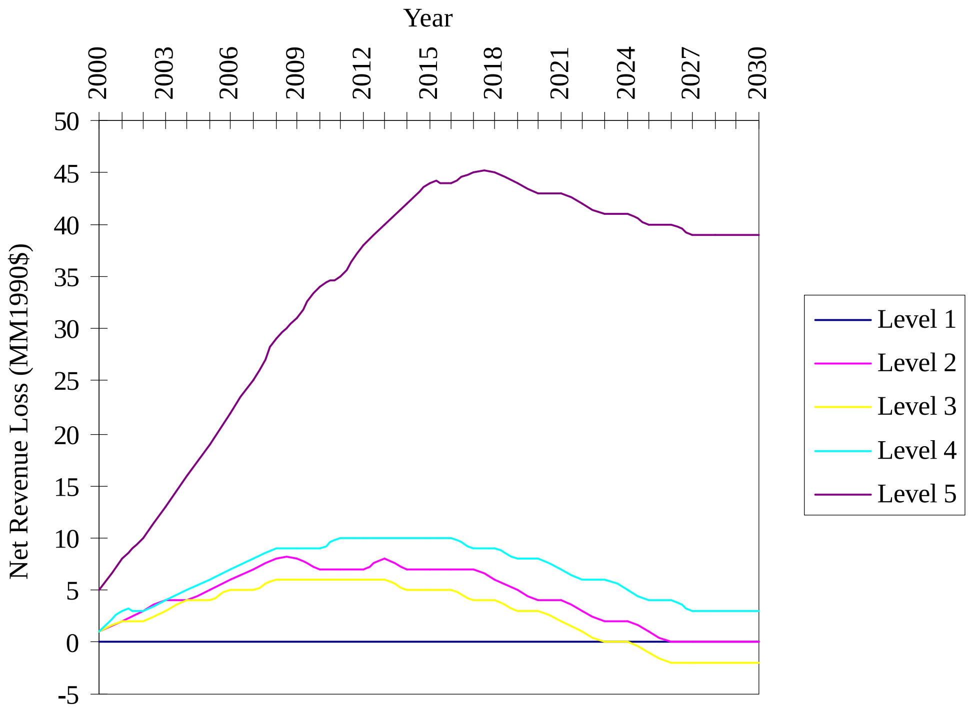

Figure 6.1 Net Revenue Loss - Cooktops

Table 6.8 Net Revenue Losses - Cooktops

	NET REVENUE LOSS (MM1990$)				
Year	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
2000	0	1	1	1	5
2001	0	2	2	3	8
2002	0	3	2	3	10
2003	0	4	3	4	13
2004	0	4	4	5	16
2005	0	5	4	6	19
2006	0	6	5	7	22
2007	0	7	5	8	25
2008	0	8	6	9	29
2009	0	8	6	9	31
2010	0	7	6	9	34
2011	0	7	6	10	35
2012	0	7	6	10	38
2013	0	8	6	10	40
2014	0	7	5	10	42
2015	0	7	5	10	44
2016	0	7	5	10	44
2017	0	7	4	9	45
2018	0	6	4	9	45
2019	0	5	3	8	44
2020	0	4	3	8	43
2021	0	4	2	7	43
2022	0	3	1	6	42
2023	0	2	0	6	41
2024	0	2	0	5	41
2025	0	1	-1	4	40
2026	0	0	-2	4	40
2027	0	0	-2	3	39
2028	0	0	-2	3	39
2029	0	0	-2	3	39
2030	0	0	-2	3	39
Total	**0**	**132**	**83**	**202**	**1035**

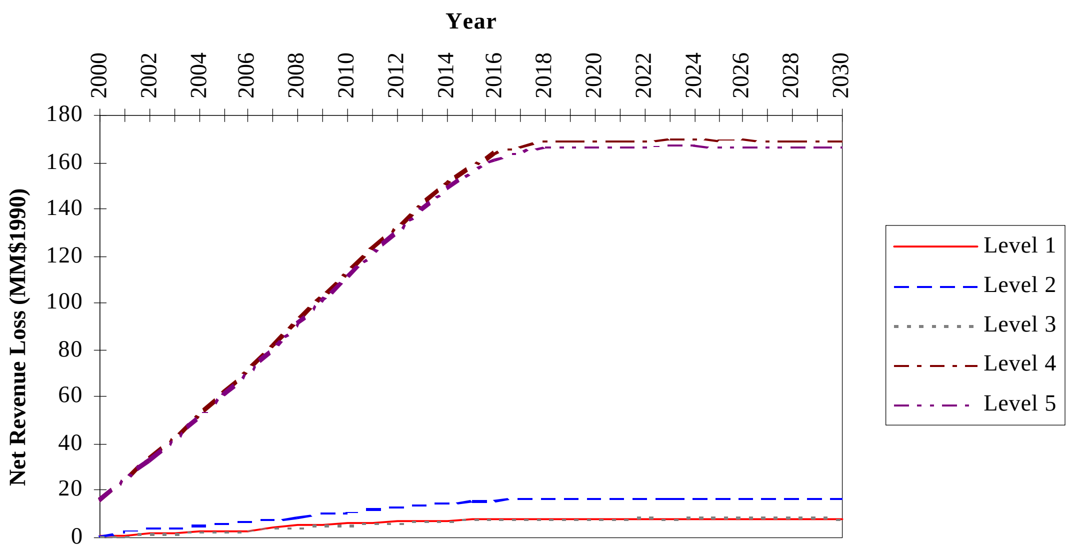

Figure 6.2 Net Revenue Loss - Ovens

Table 6.9 Net Revenue Losses - Ovens

	NET REVENUE LOSS (MM1990$)				
Year	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
2000	1	1	1	16	16
2001	1	3	1	25	25
2002	2	4	2	34	33
2003	2	4	2	43	42
2004	3	5	3	52	51
2005	3	6	3	62	61
2006	3	7	3	71	70
2007	4	8	4	82	80
2008	5	9	4	92	91
2009	5	11	5	103	101
2010	6	11	5	113	111
2011	6	12	6	123	121
2012	7	13	6	132	130
2013	7	14	7	142	140
2014	7	15	7	151	149
2015	8	16	8	158	156
2016	8	16	8	164	161
2017	8	17	8	167	165
2018	8	17	8	169	167
2019	8	17	8	169	167
2020	8	17	8	169	167
2021	8	17	8	169	167
2022	8	17	9	169	167
2023	8	17	8	170	168
2024	8	17	9	170	168
2025	8	17	9	169	167
2026	8	17	9	170	167
2027	8	17	9	169	167
2028	8	17	9	169	167
2029	8	17	9	169	167
2030	8	17	8	169	167
Total	**190**	**393**	**194**	**3930**	**3876**

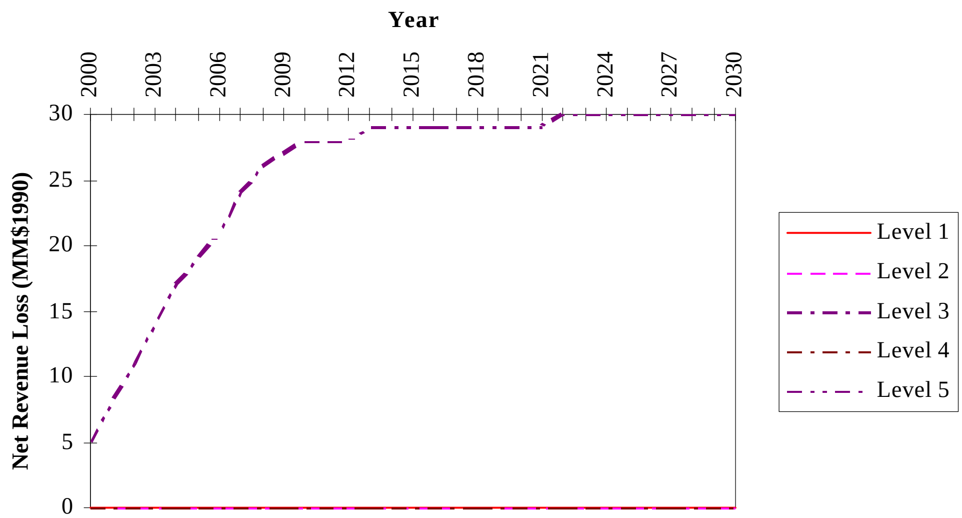

Figure 6.3 Net Revenue Loss - Microwaves

Table 6.10 Net Revenue Losses - Microwaves

Year	NET REVENUE LOSS (MM1990$) Level 1	Level 2	Level 3	Level 4	Level 5
2000	0	0	0	0	5
2001	0	0	0	0	8
2002	0	0	0	0	11
2003	0	0	0	0	14
2004	0	0	0	0	17
2005	0	0	0	0	19
2006	0	0	0	0	21
2007	0	0	0	0	24
2008	0	0	0	0	26
2009	0	0	0	0	27
2010	0	0	0	0	28
2011	0	0	0	0	28
2012	0	0	0	0	28
2013	0	0	0	0	29
2014	0	0	0	0	29
2015	0	0	0	0	29
2016	0	0	0	0	29
2017	0	0	0	0	29
2018	0	0	0	0	29
2019	0	0	0	0	29
2020	0	0	0	0	29
2021	0	0	0	0	29
2022	0	0	0	0	30
2023	0	0	0	0	30
2024	0	0	0	0	30
2025	0	0	0	0	30
2026	0	0	0	0	30
2027	0	0	0	0	30
2028	0	0	0	0	30
2029	0	0	0	0	30
2030	0	0	0	0	30
Total	**0**	**0**	**0**	**0**	787

Total residential electrical rates would increase 0.003 ¢/kWh and 0.01 ¢/kWh) in 2000 and 2005, respectively, if ovens are subject to level 5 efficiency levels, cooktops are subject to level 5 efficiency levels, microwaves are subject to level 5 efficiency levels, and regulators only change residential rates to compensate for any loss in revenue.

Tables 6.11 to 6.13 show the present value of net revenue losses at a 5% real utility discount rate for all energy efficicney levels and for the two assumptions about regulatory behavior. This discount rate is based on an assumed average utility capital structure and current rates of return.

Table 6.11 Cumulative Present Value of Revenue Losses - Cooktops

CUMULATIVE PRESENT VALUE OF LOST REVENUES (M$1990)					
Regulatory Lag	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
None	0	0	0	0	0
1998-2002	0	4	3	4	13
1998-2030	0	39	27	53	231

Table 6.12 Cumulative Present Value of Revenue Losses - Ovens

CUMULATIVE PRESENT VALUE OF LOST REVENUES (M$1990)					
Regulatory Lag	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
None	0	0	0	0	0
1998-2002	2	5	2	44	44
1998-2030	41	84	41	839	827

Table 6.13 Cumulative Present Value of Revenue Losses - Microwaves

CUMULATIVE PRESENT VALUE OF LOST REVENUES (M$1990)					
Regulatory Lag	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
None	0	0	0	0	0
1998-2002	0	0	0	0	14
1998-2030	0	0	0	0	185

a 56% chance of a decrease in ROE, with an expected decrease of 0.77%. These results are shown in Table 5.2. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

Microwave Ovens

The analysis shows that, compared to the base case, at energy efficiency levels 1 to 3 the microwave oven industry will experience no change in ROE because by design, efficiency levels 1 through 4 are the same as the baseline case. At efficiency level 5 there is approximately a 67% chance of an increase in ROE, with an expected increase of 1.16%. These results are shown in Table 5.3. The probabilities of change are computed from the expected change, the standard error of this estimate, and the assumption of a normal distribution.

Qualitative Analysis

According to reports from within the industry, kitchen range and oven manufacturing (including microwave ovens) is characterized by economies of scale; this means that for the purposes of price determination there are fixed costs. Depending on the efficiency level considered, these costs are estimated to be about 10% of total costs. Increases in fixed costs cannot be passed on, which implies that the markup over variable cost must be approximately 10% if the typical firm is to have a near-average ROE.

To the extent that this markup is the same after energy efficiency levels are imposed, and to the extent that efficiency levels induce an increase in variable costs, such costs will be more than completely passed on in the form of a price increase. The price increase is in itself is profitable, but it also tends to reduce profit because of the negative effect that a price increase typically has on sales. If energy efficiency levels an increase in fixed costs, this cost cannot be passed on and will negatively influence profit. Because of the mandated increase in efficiency, operating costs will necessarily decline, which will tend to increase profit by making kitchen ranges and ovens more attractive and thereby increase demand. (However, this effect is smaller for kitchen ranges and ovens than for most other appliances.) Also, demand is specified as a function of purchase price and operating cost (i.e., life-cycle cost) under constant life-cycle cost elasticity. Therefore as price changes, so does price elasticity, and consequently, markup. (For instance, as price rises, price elasticity rises, and markup falls.)

Quantitative Analysis

Tables 5.1, 5.2, and 5.3 summarize all essential outputs from the LBNL-MAM simulations using the long-run primary scenario for cooktops, ovens, and microwave ovens, respectively. Tables 5.4, 5.5, and 5.6 summarize the outputs from the industry net present value module of the LBNL-MAM. Three other scenarios are summarized and discussed in the sensitivity section, 5.4.

Once the above interpretations are understood, the results of the model concerning the long-run impact of energy efficiency levels on the kitchen range and oven and microwave ovens manufacturing industries can be read from the output table.

Table 5.1 Cooktops: Primary Scenario – Long-Run

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.43	1.43	1.44	1.44	1.43	1.36
% change		0.00%	0.11%	0.19%	-0.07%	-4.98%
S.E.		0.63%	1.02%	1.55%	1.67%	13.42%
Price	$103.60	$103.60	$104.74	$105.18	$106.82	$144.68
% change		0.00%	1.10%	1.52%	3.11%	39.65%
S.E.		1.62%	1.94%	1.98%	2.69%	14.00%
Revenue (in $M)	148.65	148.65	150.45	151.20	153.16	197.27
% change		0.00%	1.21%	1.72%	3.03%	32.70%
S.E.		1.18%	1.63%	1.94%	2.32%	19.33%
Net Income (in $M)	7.85	7.85	7.85	7.89	7.95	9.15
Difference		0.00	0.01	0.04	0.11	1.30
S.E.		0.11	0.19	0.25	0.33	3.80
ROE	10.84%	10.84%	10.77%	10.78%	10.78%	10.42%
Difference		0.00%	-0.07%	-0.06%	-0.05%	-0.42%
S.E.		0.10%	0.18%	0.21%	0.28%	2.25%

Table 5.2 Ovens: Primary Scenario – Long-Run

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.049	1.049	1.049	1.046	0.982	0.847
% change		0.05%	-0.01%	-0.24%	-6.36%	-19.29%
S.E.		0.39%	0.78%	1.53%	8.02%	12.06%
Price	$213.17	$213.58	$214.47	$217.41	$259.12	$342.42
% change		0.19%	0.61%	1.99%	21.56%	60.63%
S.E.		0.59%	0.68%	1.08%	7.40%	20.58%
Revenue (in $M)	223.61	224.15	224.95	227.52	254.53	289.91
% change		0.24%	0.60%	1.75%	13.82%	29.65%
S.E.		0.42%	0.75%	1.41%	9.83%	23.22%
Net Income (in $M)	11.65	11.65	11.67	11.66	12.38	13.04
Difference		0.00	0.02	0.01	0.73	1.39
S.E.		0.08	0.15	0.34	2.53	7.91
ROE	10.53%	10.51%	10.51%	10.35%	10.33%	9.75%
Difference		-0.02%	-0.02%	-0.17%	-0.19%	-0.77%
S.E.		0.05%	0.08%	0.23%	1.76%	4.87%

Table 5.3 Microwave Ovens: Primary Scenario – Long-Run

	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.72	0.72	0.72	0.72	0.72	0.62
% change		0.00%	0.00%	0.00%	0.00%	-13.54%
S.E.		0.00%	0.00%	0.00%	0.00%	9.71%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$203.60
% change		0.00%	0.00%	0.00%	0.00%	34.66%
S.E.		0.00%	0.00%	0.00%	0.00%	11.70%
Revenue (in $M)	109.23	109.23	109.23	109.23	109.23	127.16
% change		0.00%	0.00%	0.00%	0.00%	16.42%
S.E.		0.00%	0.00%	0.00%	0.00%	14.33%
Net Income (in $M)	2.01	2.01	2.01	2.01	2.01	2.59
Difference		0.00	0.00	0.00	0.00	0.58
S.E.		0.00	0.00	0.00	0.00	1.75
ROE	3.65%	3.65%	3.65%	3.65%	3.65%	4.81%
Difference		0.00%	0.00%	0.00%	0.00%	1.16%
S.E.		0.00%	0.00%	0.00%	0.00%	3.03%

Table 5.4 Cooktops: Industry Net Present Values

SUMMARY TABLE	PRE-REGULATION	POST-REGULATION				
	Base	Level 1	Level 2	Level 3	Level 4	Level 5
SHIPMENTS (UNITS)	7.17	7.09	7.10	7.10	7.08	6.68
Difference		-0.08	-0.08	-0.07	-0.09	-0.50
% Change		-1.16%	-1.07%	-0.99%	-1.29%	-6.94%
PRICE ($ UNIT)	$103.60	$109.30	$110.48	$110.93	$112.82	$156.53
Difference		5.70	6.88	7.33	9.22	52.93
% Change		5.50%	6.64%	7.08%	8.90%	51.09%
TOTAL REVENUES (in $M)	743.27	775.04	784.16	787.96	798.97	1045.05
Difference		31.77	40.89	44.69	55.70	301.78
% Change		4.27%	5.50%	6.01%	7.49%	40.60%
PROFIT AFTER TAX (in $M)	28.54	31.63	31.86	32.12	33.49	64.23
Difference		3.09	3.31	3.57	4.95	35.69
% Change		10.83%	11.61%	12.52%	17.35%	125.05%
NET CASH FLOW (in $M)	22.97	20.66	19.33	18.94	18.45	7.36
Difference		-2.31	-3.64	-4.02	-4.52	-15.61
% Change		-10.06%	-15.84%	-17.52%	-19.66%	-67.97%
INDUSTRY VALUE (in $M)	191.39	197.95	198.12	198.61	200.16	228.34
Difference		6.55	6.73	7.21	8.77	36.95
% Change		3.42%	3.52%	3.77%	4.58%	19.31%

Table 5.5 Ovens: Industry Net Present Values

SUMMARY TABLE	PRE-REGULATION	POST-REGULATION				
	Base	Level 1	Level 2	Level 3	Level 4	Level 5
SHIPMENTS (UNITS)	5.25	5.20	5.20	5.18	4.81	4.08
Difference		-0.04	-0.04	-0.07	-0.44	-1.16
% Change		-0.77%	-0.85%	-1.26%	-8.32%	-22.18%
PRICE ($ UNIT)	$213.17	$217.50	$218.47	$222.33	$270.62	$368.64
Difference		4.33	5.30	9.16	57.45	155.47
% Change		2.03%	2.49%	4.30%	26.95%	72.93%
TOTAL REVENUES (in $M)	1118.06	1131.96	1136.16	1151.44	1301.24	1504.58
Difference		13.89	18.10	33.37	183.17	386.51
% Change		1.24%	1.62%	2.98%	16.38%	34.57%
PROFIT AFTER TAX (in $M)	42.93	44.50	44.77	49.45	70.67	108.61
Difference		1.57	1.84	6.51	27.74	65.68
% Change		3.65%	4.28%	15.17%	64.61%	152.98%
NET CASH FLOW (in $M)	34.55	33.76	33.31	35.39	31.15	34.52
Difference		-0.79	-1.24	0.84	-3.40	-0.03
% Change		-2.30%	-3.59%	2.44%	-9.84%	-0.08%
INDUSTRY VALUE (in $M)	287.90	291.47	291.96	292.47	318.89	348.06
Difference		3.56	4.06	4.56	30.99	60.16
% Change		1.24%	1.41%	1.59%	10.77%	20.90%

Table 5.6 Microwave Ovens: Industry Net Present Values

SUMMARY TABLE	PRE-REGULATION	POST-REGULATION				
	Base	Level 1	Level 2	Level 3	Level 4	Level 5
SHIPMENTS (UNITS)	3.61	3.61	3.61	3.61	3.61	3.07
Difference		0.00	0.00	0.00	0.00	-0.54
% Change		0.00%	0.00%	0.00%	0.00%	-14.95%
PRICE ($ UNIT)	$151.20	$151.20	$151.20	$151.20	$151.20	$210.47
Difference		0.00	0.00	0.00	0.00	59.27
% Change		0.00%	0.00%	0.00%	0.00%	39.20%
TOTAL REVENUES (in $M)	546.13	546.13	546.13	546.13	546.13	646.54
Difference		0.00	0.00	0.00	0.00	100.41
% Change		0.00%	0.00%	0.00%	0.00%	18.38%
PROFIT AFTER TAX (in $M)	20.97	20.97	20.97	20.97	20.97	27.60
Difference		0.00	0.00	0.00	0.00	6.62
% Change		0.00%	0.00%	0.00%	0.00%	31.59%
NET CASH FLOW (in $M)	16.88	16.88	16.88	16.88	16.88	6.43
Difference		0.00	0.00	0.00	0.00	-10.45
% Change		0.00%	0.00%	0.00%	0.00%	-61.89%
INDUSTRY VALUE (in $M)	140.63	140.63	140.63	140.63	140.63	155.04
Difference		0.00	0.00	0.00	0.00	14.41
% Change		0.00%	0.00%	0.00%	0.00%	10.25%

5.2. SHORT-RUN IMPACTS

In the short run, capacity may not adjust as needed to meet the predicted long-run change in demand resulting from energy efficiency levels. This situation could have either of the following consequences: If energy efficiency levels cause a decrease in demand, stiffer-than-normal short-run price competition will result and price will fall below its long-run level, lowering profits. If efficiency levels cause an increase in demand, there will be less short-run price competition than normal and price and profits will increase.

The business cycle presents the kitchen ranges and ovens manufacturing industries (and indeed all durable goods industries) with fairly sharp periodic fluctuations in demand much larger than the fluctuations predicted for any of the energy efficiency levels. These normal demand fluctuations present the same types of opportunities for price competition that will accompany fluctuations resulting from a change in efficiency levels. Regressing price on demand and a time trend for the past 18 years shows that a 10% fall in demand typically leads to a 0.3% fall in the price of kitchen ranges and ovens; a 10% demand increase has the reverse effect. This effect is taken into account as described in Section 3.3.3.2 of Volume 1 and is used to produce a short-run version of the output tables that are displayed in Table 5.7, 5.8, and 5.9. For reasons that are explained in Section 3.3.3.2, the short-run change has been overestimated. Thus all values for change in Tables 5.7, 5.8, and 5.9 should be viewed as somewhat too large in absolute value. The short-run impact on profit is also displayed in the Monte Carlo module.

Table 5.7 Cooktops: Primary Scenario – Short-Run

Scenario = Primary	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.435	1.434	1.436	1.437	1.434	1.366
% change		-0.03%	0.07%	0.15%	-0.10%	-4.82%
Price	$103.60	$103.74	$104.90	$105.35	$106.95	$143.78
% change		0.14%	1.26%	1.69%	3.24%	38.79%
Revenue (in $M)	148.65	148.81	150.63	151.40	153.32	196.37
% change		0.11%	1.33%	1.85%	3.14%	32.10%
Net Income (in $M)	7.85	8.02	8.06	8.11	8.12	8.11
Difference		0.17	0.21	0.26	0.28	0.27
ROE	10.84%	11.07%	11.04%	11.08%	11.02%	9.24%
Difference		0.24%	0.21%	0.24%	0.18%	-1.59%
S.E.		1.30%	1.39%	1.67%	1.18%	3.46%

Table 5.8 Ovens: Primary Scenario – Short-Run

Scenario = Primary	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.049	1.049	1.048	1.046	0.986	0.858
% change		0.01%	-0.05%	-0.26%	-5.97%	-18.16%
Price	$213.17	$213.77	$214.64	$217.51	$256.91	$332.90
% change		0.28%	0.69%	2.04%	20.52%	56.17%
Revenue (in $M)	223.61	224.26	225.05	227.57	253.41	285.79
% change		0.29%	0.64%	1.77%	13.32%	27.81%
Net Income (in $M)	11.65	11.79	11.80	11.50	10.60	6.88
Difference		0.14	0.16	-0.15	-1.05	-4.77
ROE	10.53%	10.64%	10.63%	10.21%	8.85%	5.14%
Difference		0.11%	0.10%	-0.32%	-1.68%	-5.38%
S.E.		0.42%	0.74%	0.72%	2.79%	7.04%

Table 5.9 Microwave Ovens: Primary Scenario – Short-Run

Scenario = Primary	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.722	0.722	0.722	0.722	0.722	0.631
% change		0.00%	0.00%	0.00%	0.00%	-12.68%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$199.55
% change		-0.00%	-0.00%	-0.00%	-0.00%	31.98%
Revenue (in $M)	109.23	109.23	109.23	109.23	109.23	125.87
% change		-0.00%	-0.00%	-0.00%	-0.00%	15.24%
Net Income (in $M)	2.01	2.01	2.01	2.01	2.01	1.24
Difference		0.00	0.00	0.00	0.00	-0.77
ROE	3.65%	3.65%	3.65%	3.65%	3.65%	2.30%
Difference		-0.00%	-0.00%	-0.00%	-0.00%	-1.35%
S.E.		0.00%	0.00%	0.00%	0.00%	5.34%

5.3. IMPACT AS A FUNCTION OF FIRM SIZE

In this industry, average cost decreases with larger firm size, which means that the industry has economies of scale, and large firms (to the extent that their facilities are up-to-date) have lower average costs than small firms. This fact, coupled with the increasing competitiveness of the national market probably accounts for the continuing consolidation that has been occurring for several decades in the industry. The fact that the consolidation has been producing larger firms strongly corroborates the finding that large firms have a cost advantage.

A principal implication of consolidation is that the smaller of the major firms will tend to be in greater danger of failing or either being bought out than will the larger firms. Because of the vulnerability of smaller firms, any decrease in average profitability is more likely to seriously damage a smaller firm, and an increase in average profitability is more likely to mean the difference between success and failure for a smaller firm.

From the point of view of competitiveness, a decrease in average profitability could speed up the process of consolidation, producing a less competitive industry, and an increase in average profitability could help maintain the current level of competition. Either effect might well be temporary because in the long run the number of firms should be determined by the industry's cost structure and by the way a single firm's elasticity of demand relates to the number of competing firms. Of course, if energy efficiency levels are technologically difficult to meet, they may hurt selected smaller firms the most because such firms have less sophisticated research and development capabilities.

5.4. SENSITIVITY ANALYSIS FOR KITCHEN RANGES AND OVENS

The three following subsections discuss different aspects of the sensitivity analysis conducted by LBNL-MAM. The first subsection shows three alternative scenarios that are of interest and which deserve a more detailed analysis than those generated by chance in Monte Carlo runs. The subsection on sensitivity charts shows the implications of the uncertainty of each control variable for the prediction of ROE. The last subsection shows the use of Monte Carlo runs to find combinations of standard errors that would cause the change in ROE to be considerably more negative than is predicted. For a more complete explanation, see Sections 3.3.3.4 and C.2.1 in Chapter 3 and Appendix C, respectively, in Volume 1: Methodology.

Alternative Scenarios

The sensitivity analysis shows that price elasticity and discount rates play significant roles in determining the output of the model. The price elasticity is an industry elasticity as opposed to a single-firm elasticity. This means it measures the effect on demand of a change in price by all firms for all kitchen ranges and ovens. The estimates of standard errors which are calculated by the Monte Carlo analysis fully acknowledge the uncertainties of these two variables. However, in order to show in detail all of the ramifications of changing one or both of them, three alternative scenarios have been used.

The three scenarios are: "a high industry price elasticity" scenario where the industry price elasticity (IPE) is -1. The "low industry price elasticity" scenario changes IPE to 0. The "low discount rate scenario" sets the discount rate at 10% of its value in the primary scenario. Tables 5.10 to 5.18 show the results of running these scenarios for the kitchen ranges and ovens industry.

Sensitivity Charts

Tables 5.19 to 5.21 list the sensitivities of ROE to the control panel inputs for each product. To construct the tables, each control variable is first set to its normal value, then one is increased in absolute value by one standard error, and the change in profit is recorded. Next, the variable is returned to its normal value and the next variable is tested. Since each variable has its own standard error, the sensitivity reported in the table measures both how sensitive the model is to a change in the variable, and how uncertain the variable's value is. Note that the change in profit is simply the difference between long-run ROE and base-case ROE.

As can be seen from the tables, three control variables account for nearly all of the uncertainty in the determination of ROE. These are: 1) the industry elasticity of demand with respect to price (IPE), 2) the consumer discount rate of appliance energy savings (RD), and 3) the current proportion of long-run fixed costs (FCA). No variable may be singled out as most important because importance varies with efficiency level. Why these three variables are important, and why their importance changes from one level to the next, is discussed below.

The industry price elasticity (IPE) determines consumer reaction to the price increase imposed by energy efficeiency levels. This variable gains its importance not through any effect on pricing (which is determined only by the single-firm price elasticity), but because it translates a price increase into a decrease in sales, and any change in sales directly influences profit. Because of fixed costs, a fall in demand causes a greater reduction in revenue than in variable costs, and, consequently, a loss in profit. Probably the most important reason for the model's high sensitivity to IPE is IPE's uncertainty.[1] Because the estimates were made quite some time ago, we view the estimated value of IPE as being highly uncertain and as a result, we assigned it an uncertainty of 100%.[2]

The consumer discount rate (RD) shows a large sensitivity for exactly the same reason as IPE. In both cases, this sensitivity changes from efficiency level to efficiency level because price increase and operating cost decrease change from level to level. The percent of fixed costs (FCA) is important because of its role in the model and the uncertainty of its measurement. It determines LBNL-MAM's estimate of the firm's markup over variable cost, which, in turn, determines the firm's ability to pass on costs.

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[1] The original source of elasticities was Oak Ridge National Laboratory and are documented in DOE/CE-0029, *Consumer Products Efficiency Standards Economic Analysis Document*, U.S. Department of Energy, March 1982. These estimates were further checked against historical shipments by the LBNL-REM analysis.

[2] This means its standard error equals its mean value.

Table 5.10 Cooktops: High IPE Scenario

		Long-Run				
Scenario=Hi IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.46	1.46	1.47	1.47	1.46	1.25
% change		0.00%	0.33%	0.57%	-0.21%	-14.20%
S.E.		1.00%	1.31%	1.26%	1.62%	6.34%
Price	$103.60	$103.60	$104.74	$105.18	$106.82	$144.68
% change		0.00%	1.10%	1.52%	3.11%	39.65%
S.E.		1.56%	2.03%	1.94%	2.54%	14.08%
Revenue (in $M)	151.36	151.36	153.53	154.54	155.74	181.37
% change		0.00%	1.43%	2.10%	2.89%	19.82%
S.E.		0.54%	0.69%	0.65%	0.83%	2.45%
Net Income (in $M)	8.15	8.154	8.200	8.264	8.240	7.457
Difference		0.000	0.046	0.110	0.086	-0.697
S.E.		0.059	0.065	0.072	0.093	0.888
ROE	11.07%	11.07%	11.03%	11.07%	11.00%	9.03%
Difference		0.00%	-0.04%	-0.01%	-0.07%	-2.04%
S.E.		0.08%	0.08%	0.09%	0.12%	1.15%

Table 5.11 Ovens: High IPE Scenario

		Long-Run				
Scenario = Hi IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.061	1.062	1.060	1.053	0.871	0.558
% change		0.14%	-0.04%	-0.72%	-17.89%	-47.42%
S.E.		0.75%	0.98%	1.37%	6.57%	8.16%
Price	$213.17	$213.58	$214.47	$217.41	$259.12	$342.41
% change		0.19%	0.61%	1.99%	21.56%	60.63%
S.E.		0.56%	0.74%	1.04%	7.14%	17.85%
Revenue (in $M)	226.13	226.88	227.42	228.97	225.69	190.99
% change		0.33%	0.57%	1.26%	-0.20%	-15.54%
S.E.		0.20%	0.26%	0.38%	2.61%	5.56%
Net Income (in $M)	11.94	11.97	11.95	11.83	9.05	1.08
Difference		0.03	0.01	-0.11	-2.89	-10.86
S.E.		0.11	0.15	0.26	1.81	4.52
ROE	10.67%	10.67%	10.65%	10.44%	8.34%	1.03%
Difference		-0.00%	-0.02%	-0.23%	-2.34%	-9.64%
S.E.		0.06%	0.08%	0.19%	1.58%	4.27%

Table 5.12 Microwave Ovens: High IPE Scenario

		Long-Run				
Scenario = Hi IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.72	0.72	0.72	0.72	0.72	0.47
% change		0.00%	0.00%	0.00%	0.00%	-35.38%
S.E.		0.00%	0.00%	0.00%	0.00%	7.62%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$203.60
% change		0.00%	0.00%	0.00%	0.00%	34.66%
S.E.		0.00%	0.00%	0.00%	0.00%	11.61%
Revenue (in $M)	109.23	109.23	109.23	109.23	109.23	95.04
% change		0.00%	0.00%	0.00%	0.00%	-12.98%
S.E.		0.00%	0.00%	0.00%	0.00%	4.10%
Net Income (in $M)	2.01	2.01	2.01	2.01	2.01	0.12
Difference		0.00	0.00	0.00	0.00	-1.89
S.E.		0.00	0.00	0.00	0.00	1.44
ROE	3.65%	3.65%	3.65%	3.65%	3.65%	0.29%
Difference		0.00%	0.00%	0.00%	0.00%	-3.36%
S.E.		0.00%	0.00%	0.00%	0.00%	3.48%

Table 5.13 Cooktops: Low IPE Scenario

	Long-Run					
Scenario= Low IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.42	1.42	1.42	1.42	1.42	1.42
% change		0.00%	0.00%	0.00%	-0.00%	-0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%
Price	$103.60	$103.60	$104.74	$105.18	$106.82	$144.68
% change		0.00%	1.10%	1.52%	3.11%	39.65%
S.E.		1.51%	1.93%	2.09%	2.40%	13.04%
Revenue (in $M)	147.32	147.32	148.94	149.56	151.89	205.73
% change		0.00%	1.10%	1.52%	3.11%	39.65%
S.E.		1.51%	1.93%	2.09%	2.40%	13.04%
Net Income (in $M)	7.69	7.69	7.68	7.70	7.81	10.04
Difference		0.00	-0.01	0.01	0.12	2.35
S.E.		0.15	0.20	0.20	0.26	1.73
ROE	10.72%	10.72%	10.63%	10.63%	10.67%	11.10%
Difference		0.00%	-0.08%	-0.08%	-0.05%	0.38%
S.E.		0.14%	0.17%	0.17%	0.23%	1.39%

Table 5.14 Ovens: Low IPE Scenario

		Long-Run				
Scenario=Low IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.043	1.043	1.043	1.043	1.043	1.043
% change		0.00%	-0.00%	-0.00%	-0.00%	-0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%
Price	$213.17	$213.58	$214.47	$217.41	$259.12	$342.42
% change		0.19%	0.61%	1.99%	21.56%	60.63%
S.E.		0.59%	0.70%	1.10%	6.89%	19.97%
Revenue (in $M)	222.37	222.79	223.72	226.79	270.30	357.17
% change		0.19%	0.61%	1.99%	21.56%	60.62%
S.E.		0.59%	0.70%	1.10%	6.89%	19.96%
Net Income (in $M)	11.50	11.50	11.53	11.57	14.19	21.17
Difference		-0.01	0.02	0.07	2.69	9.66
S.E.		0.12	0.15	0.28	2.07	7.99
ROE	10.45%	10.43%	10.44%	10.31%	11.27%	13.80%
Difference		-0.02%	-0.02%	-0.14%	0.82%	3.34%
S.E.		0.08%	0.10%	0.21%	1.40%	4.30%

Table 5.15 Microwave Ovens: Low IPE Scenario

		Long-Run				
Scenario= Low IPE	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.72	0.72	0.72	0.72	0.72	0.72
% change		0.00%	0.00%	0.00%	0.00%	-0.00%
S.E.		0.00%	0.00%	0.00%	0.00%	0.00%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$203.60
% change		0.00%	0.00%	0.00%	0.00%	34.66%
S.E.		0.00%	0.00%	0.00%	0.00%	11.10%
Revenue (in $M)	109.23	109.23	109.23	109.23	109.23	147.08
% change		0.00%	0.00%	0.00%	0.00%	34.65%
S.E.		0.00%	0.00%	0.00%	0.00%	11.10%
Net Income (in $M)	2.01	2.01	2.01	2.01	2.01	4.12
Difference		0.00	0.00	0.00	0.00	2.11
S.E.		0.00	0.00	0.00	0.00	1.98
ROE	3.65%	3.65%	3.65%	3.65%	3.65%	6.77%
Difference		0.00%	0.00%	0.00%	0.00%	3.12%
S.E.		0.00%	0.00%	0.00%	0.00%	3.15%

Table 5.16 Cooktops: Low Discount Rate Scenario

		Long-Run				
Scenario= Low RD	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.72	1.72	1.78	1.82	1.83	2.25
% change		0.00%	3.63%	5.55%	6.16%	30.83%
S.E.		0.32%	0.48%	0.58%	0.69%	5.37%
Price	$102.26	$102.26	$103.22	$103.54	$105.05	$139.83
% change		0.00%	0.93%	1.24%	2.73%	36.74%
S.E.		1.38%	1.74%	1.90%	2.31%	13.12%
Revenue (in $M)	176.10	176.10	184.19	188.19	192.04	315.04
% change		0.00%	4.59%	6.86%	9.05%	78.90%
S.E.		1.06%	1.36%	1.52%	1.83%	10.90%
Net Income (in $M)	9.76	9.76	10.22	10.47	10.60	15.82
Difference		0.00	0.46	0.71	0.84	6.06
S.E.		0.02	0.13	0.19	0.20	1.15
ROE	11.36%	11.36%	11.44%	11.49%	11.48%	12.19%
Difference		0.00%	0.08%	0.14%	0.13%	0.84%
S.E.		0.05%	0.14%	0.19%	0.20%	0.85%

Table 5.17 Ovens: Low Discount Rate Scenario

	Long-Run					
Scenario = Low RD	1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	1.170	1.186	1.201	1.247	1.452	1.023
% change		1.38%	2.64%	6.59%	24.06%	-12.58%
S.E.		0.26%	0.35%	0.58%	4.90%	6.39%
Price	$211.55	$211.77	$212.44	$214.69	$250.87	$330.18
% change		0.10%	0.42%	1.48%	18.58%	56.07%
S.E.		0.52%	0.65%	0.91%	6.57%	17.91%
Revenue (in $M)	247.52	251.20	255.13	267.73	364.14	337.70
% change		1.48%	3.07%	8.16%	47.11%	36.43%
S.E.		0.27%	0.34%	0.49%	3.06%	4.50%
Net Income (in $M)	13.41	13.63	13.84	14.57	18.73	12.32
Difference		0.22	0.44	1.16	5.32	-1.09
S.E.		0.08	0.14	0.36	1.26	1.88
ROE	10.92%	10.94%	10.96%	10.97%	11.21%	8.14%
Difference		0.02%	0.04%	0.06%	0.30%	-2.78%
S.E.		0.06%	0.11%	0.26%	0.71%	1.44%

Table 5.18 Microwave Ovens: Low Discount Rate Scenario

Scenario = Low RD	Long-Run 1996 BASE	Lev 1	Lev 2	Lev 3	Lev 4	Lev 5
Shipments (in Mil)	0.72	0.72	0.72	0.72	0.72	0.47
% change		0.00%	0.00%	0.00%	0.00%	-35.38%
S.E.		0.00%	0.00%	0.00%	0.00%	7.62%
Price	$151.20	$151.20	$151.20	$151.20	$151.20	$203.60
% change		0.00%	0.00%	0.00%	0.00%	34.66%
S.E.		0.00%	0.00%	0.00%	0.00%	11.61%
Revenue (in $M)	109.23	109.23	109.23	109.23	109.23	95.04
% change		0.00%	0.00%	0.00%	0.00%	-12.98%
S.E.		0.00%	0.00%	0.00%	0.00%	4.10%
Net Income (in $M)	2.01	2.01	2.01	2.01	2.01	0.12
Difference		0.00	0.00	0.00	0.00	-1.89
S.E.		0.00	0.00	0.00	0.00	1.44
ROE	3.65%	3.65%	3.65%	3.65%	3.65%	0.29%
Difference		0.00%	0.00%	0.00%	0.00%	-3.36%
S.E.		0.00%	0.00%	0.00%	0.00%	3.48%

Table 5.19 Cooktops: Sensitivity of ROE to a 1 S.E. Change in Control Variables

Control Variables			Possible Energy Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.201	-0.462	0.00%	0.02%	0.03%	-0.01%	-1.05%
RD	0.258	0.593	0.00%	0.08%	0.13%	0.18%	1.19%
ECC	0.068	0.075	0.00%	0.00%	0.00%	-0.00%	-0.03%
EP	0.039	0.049	0.00%	-0.01%	-0.01%	-0.01%	-0.09%
FCA	0.100	0.160	0.00%	-0.02%	-0.00%	0.03%	0.61%
F1X	0.200	0.348	0.00%	0.00%	-0.00%	-0.02%	-0.44%
CC.N	0.498	0.607	-0.00%	-0.00%	-0.00%	-0.01%	-0.14%
dVC.N	4.548	6.100	0.06%	0.07%	0.08%	0.09%	0.24%
ro.N	0.000	0.144	0.00%	0.01%	0.01%	-0.01%	-0.42%

Table 5.20 Ovens: Sensitivity of ROE to a 1 S.E. Change in Control Variables

Control Variables			Possible Energy Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.440	-0.440	0.01%	-0.00%	-0.04%	-1.38%	-5.69%
RD	0.389	0.894	0.02%	0.03%	0.08%	0.51%	0.84%
ECC	0.068	0.075	-0.00%	-0.00%	-0.01%	-0.03%	-0.12%
EP	0.039	0.049	-0.00%	-0.00%	-0.01%	-0.02%	-0.01%
FCA	0.100	0.160	-0.00%	0.00%	0.02%	0.45%	1.34%
F1X	0.200	0.348	-0.00%	-0.00%	-0.13%	-0.36%	-0.75%
CC.N	0.274	0.334	-0.00%	-0.00%	-0.03%	-0.12%	-0.43%
dVC.N	3.305	4.433	0.03%	0.04%	0.05%	0.17%	0.00%
ro.N	0.000	0.144	0.00%	-0.00%	-0.02%	-0.45%	-1.55%

Table 5.21 Microwave Ovens: Sensitivity of ROE to a 1 S.E. Change in Control Variables

Control Variables			Possible Energy Efficiency Levels				
Name	Value	Changed	1	2	3	4	5
IPE	-0.490	-0.490	0.00%	0.00%	0.00%	0.00%	-2.84%
RD	2.500	5.748	0.00%	0.00%	0.00%	0.00%	0.06%
ECC	0.068	0.075	0.00%	0.00%	0.00%	0.00%	-0.00%
EP	-0.032	-0.022	0.00%	0.00%	0.00%	0.00%	0.19%
FCA	0.100	0.160	0.00%	0.00%	0.00%	0.00%	1.41%
F1X	0.200	0.348	0.00%	0.00%	0.00%	0.00%	0.00%
CC.N	0.000	0.000	0.00%	0.00%	0.00%	0.00%	0.00%
dVC.N	0.000	0.000	0.00%	0.00%	0.00%	0.00%	0.34%
ro.N	0.000	0.144	0.00%	0.00%	0.00%	0.00%	-0.79%

Monte Carlo Analysis

The Monte Carlo approach is described in Section 3.3.3.4 in Chapter 3, Volume 1: Methodology and the standard errors it generates are reported in the output tables. This section examines two runs in more detail.

Tables 5.22, 5.23, and 5.24 shows the control panel from two Monte Carlo runs each for cooktops, ovens, and microwave ovens. These two runs were selected because they showed a decrease in long-run ROE. (All Monte Carlo runs were done for efficiency level 1.) The primary factor affecting the results was the industry price elasticity (IPE), which was randomly chosen more than two standard deviations beyond its estimated value.

It should also be noted that the discount rate plays a lesser but supporting role in the outcome of the various scenarios.

Table 5.22 Cooktops: Monte Carlo Runs

COOKTOP ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari-ation	Progrm Value	Name
Price Elasticity		-0.201	-0.80	100%	-0.103	IPE
Consumer Discount Rate		25.80%	1.90	100%	1.250	RD
Equity Cost of Capital		0.068	-0.43	10%	0.065	ECC
Economic Profit		0.039	1.20	1%	0.051	EP
L-R Fixed Part of Costs & Assets		0.100	2.40	50%	0.311	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	-0.44	60%	0.157	F1X
One-Time Capital Costs		0.498	1.61	20%	0.686	CC.N
Unit Variable Cost Increase		$4.55	-1.58	30%	2.861	dVC.N
Elasticity Curve Parameter		0.000	-3.08	14%	-0.445	ro.N
Short Run Price Response to Demand		0.157	-1.48	76%	0.057	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.41	1.41	0.31%	0.00%	1.41	
Price	$111.57	$108.21	-3.01%	0.00%	$108.16	
Revenue (in $M)	156.96	152.71	-2.71%	0.00%	152.65	
Net Income	15.12	13.75	-1.37	0.00	13.73	
ROE	21.26%	19.47%	-1.79%	0.00%	19.43%	
Efficiency Level = 1			Trys =	28839		

COOKTOP ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari-ation	Progrm Value	Name
Price Elasticity		-0.201	-0.12	100%	-0.182	IPE
Consumer Discount Rate		25.80%	1.83	100%	1.182	RD
Equity Cost of Capital		0.068	0.23	10%	0.070	ECC
Economic Profit		0.039	-0.06	1%	0.038	EP
L-R Fixed Part of Costs & Assets		0.100	2.63	50%	0.347	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	0.96	60%	0.341	F1X
One-Time Capital Costs		0.498	-0.93	20%	0.415	CC.N
Unit Variable Cost Increase		$4.55	-1.72	30%	2.743	dVC.N
Elasticity Curve Parameter		0.000	-2.17	14%	-0.313	ro.N
Short Run Price Response to Demand		0.157	0.85	76%	0.279	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.40	1.41	0.59%	0.00%	1.41	
Price	$111.01	$107.47	-3.19%	0.00%	$107.13	
Revenue (in $M)	155.05	151.00	-2.61%	0.00%	150.61	
Net Income	13.69	12.43	-1.26	0.00	12.17	
ROE	19.36%	17.68%	-1.68%	0.00%	17.32%	
Efficiency Level = 1			Trys =	9330		

Table 5.23 Ovens: Monte Carlo Runs

OVEN ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari-ation	Progrm Value	Name
Price Elasticity		-0.440	-0.93	100%	-0.202	IPE
Consumer Discount Rate		38.90%	-1.42	100%	0.119	RD
Equity Cost of Capital		0.068	-0.25	10%	0.066	ECC
Economic Profit		0.039	0.98	1%	0.049	EP
L-R Fixed Part of Costs & Assets		0.100	2.71	50%	0.360	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	-0.29	60%	0.170	F1X
One-Time Capital Costs		0.274	-0.94	20%	0.228	CC.N
Unit Variable Cost Increase		$3.30	-1.68	30%	2.018	dVC.N
Elasticity Curve Parameter		0.000	-1.94	14%	-0.280	ro.N
Short Run Price Response to Demand		0.157	-0.79	76%	0.092	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.06	1.07	0.44%	0.05%	1.07	
Price	$207.29	$205.16	-1.03%	0.19%	$205.63	
Revenue (in $M)	220.76	219.45	-0.59%	0.24%	219.84	
Net Income	9.71	9.12	-0.59	0.00	9.42	
ROE	8.66%	8.13%	-0.53%	-0.02%	8.40%	
Efficiency Level = 1			Trys =	4428		

OVEN ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari-ation	Progrm Value	Name
Price Elasticity		-0.440	-0.52	100%	-0.285	IPE
Consumer Discount Rate		38.90%	1.61	100%	1.481	RD
Equity Cost of Capital		0.068	0.05	10%	0.068	ECC
Economic Profit		0.039	0.31	1%	0.042	EP
L-R Fixed Part of Costs & Assets		0.100	2.60	50%	0.341	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	0.86	60%	0.323	F1X
One-Time Capital Costs		0.274	1.70	20%	0.385	CC.N
Unit Variable Cost Increase		$3.30	-2.28	30%	1.691	dVC.N
Elasticity Curve Parameter		0.000	-1.79	14%	-0.259	ro.N
Short Run Price Response to Demand		0.157	1.54	76%	0.447	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	1.04	1.04	0.36%	0.05%	1.04	
Price	$214.90	$212.40	-1.16%	0.19%	$212.36	
Revenue (in $M)	223.25	221.44	-0.81%	0.24%	221.41	
Net Income	12.78	12.13	-0.65	0.00	12.11	
ROE	11.65%	11.06%	-0.59%	-0.02%	11.04%	
Efficiency Level = 1			Trys =	12425		

Table 5.24 Microwave Ovens: Monte Carlo Runs

MICROWAVE OVEN ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity		-0.490	1.23	100%	-1.364	IPE
Consumer Discount Rate		250.00%	2.24	100%	16.100	RD
Equity Cost of Capital		0.068	1.02	10%	0.075	ECC
Economic Profit		-0.032	1.93	1%	-0.012	EP
L-R Fixed Part of Costs & Assets		0.100	-0.23	50%	0.090	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	1.33	60%	0.417	F1X
One-Time Capital Costs		0.000	0.70	20%	0.000	CC.N
Unit Variable Cost Increase		$47.43	-1.20	30%	33.323	dVC.N
Elasticity Curve Parameter		0.000	0.37	14%	0.054	ro.N
Short Run Price Response to Demand		0.157	0.05	76%	0.162	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	0.72	0.53	-25.94%	-13.54%	0.56	
Price	$151.20	$187.91	24.28%	34.66%	$181.19	
Revenue (in $M)	109.23	100.53	-7.96%	16.42%	102.01	
Net Income	3.48	1.98	-1.50	0.58	0.13	
ROE	6.31%	4.34%	-1.97%	1.16%	0.28%	
			Trys =	13		

MICROWAVE OVEN ANALYSIS CONTROL FACTORS		Input Value	Cntrl	Vari- ation	Progrm Value	Name
Price Elasticity		-0.490	1.62	100%	-1.892	IPE
Consumer Discount Rate		250.00%	-1.27	100%	0.870	RD
Equity Cost of Capital		0.068	1.22	10%	0.077	ECC
Economic Profit		-0.032	1.62	1%	-0.015	EP
L-R Fixed Part of Costs & Assets		0.100	-0.73	50%	0.071	FCA
L-R Fixed Part of 1-X Cap. Cost		0.200	1.19	60%	0.387	F1X
One-Time Capital Costs		0.000	-2.06	20%	0.000	CC.N
Unit Variable Cost Increase		$47.43	1.14	30%	66.271	dVC.N
Elasticity Curve Parameter		0.000	0.75	14%	0.108	ro.N
Short Run Price Response to Demand		0.157	-0.21	76%	0.136	SRPR
	NAECA	NEW		PREVIOUS	NEW	
SUMMARY	BASE	L-RUN	CHANGE	CHANGE	S-RUN	
Shipments	0.72	0.34	-53.61%	-13.54%	0.39	
Price	$151.20	$221.44	46.46%	34.66%	$207.42	
Revenue (in $M)	109.23	74.22	-32.05%	16.42%	80.14	
Net Income	3.39	-0.49	-3.88	0.58	-2.97	
ROE	6.15%	-1.41%	-7.56%	1.16%	-8.55%	
Efficiency Level = 1			Trys =	10		

$$\mathrm{PWF} = \sum_{t=1}^{N} \frac{1}{(1 + r)^t} = \frac{1}{r}\left[1 - \frac{1}{(1 + r)^N}\right] \qquad \textbf{(4.3)}$$

The LCC is calculated for each class in the year levels are set, using a discount rate, *r*.

4.1.1 LCC Data Inputs

The installed consumer cost is composed of a retail price—based on factory costs (from Volume 2, Engineering Analysis, Chapter 1) and factory, distributor, and retail markups (from Volume 2, LBNL-MAM, Chapter 5)—plus installation costs (where applicable). Operating expenses include energy expenditures and maintenance costs. Annual energy consumption is the average unit energy consumption in the field (from LBNL-REM). Annual energy expense to the consumer is annual energy consumption times energy price. Annual energy consumption values are discussed in detail in Volume 2, Appendix A of this Technical Support Document (TSD). Energy price is the projected average residential energy price for 1999 from DOE/EIA's *Annual Energy Outlook 1995* (1) times an end-use factor of 1.11 for electric and 1.04 for gas, both derived from DOE/EIA's 1990 *Residential Energy Consumption Survey*(2). Annual operating expenses are discounted to the year of purchase (1999) and summed over the average life of the product (from LBNL-REM) to obtain a present value. For the residential sector, the discount rate is 6% real, with sensitivity analyses performed at 2% and 15% real.

4.1.2 LCC Results

Figures 4.1 to 4.8 show the LCCs by design option. The values used to produce these figures are presented in Tables 4.1 to 4.8.

Figure 4.1 Life-Cycle Costs for Electric Cooktop, Coil Element

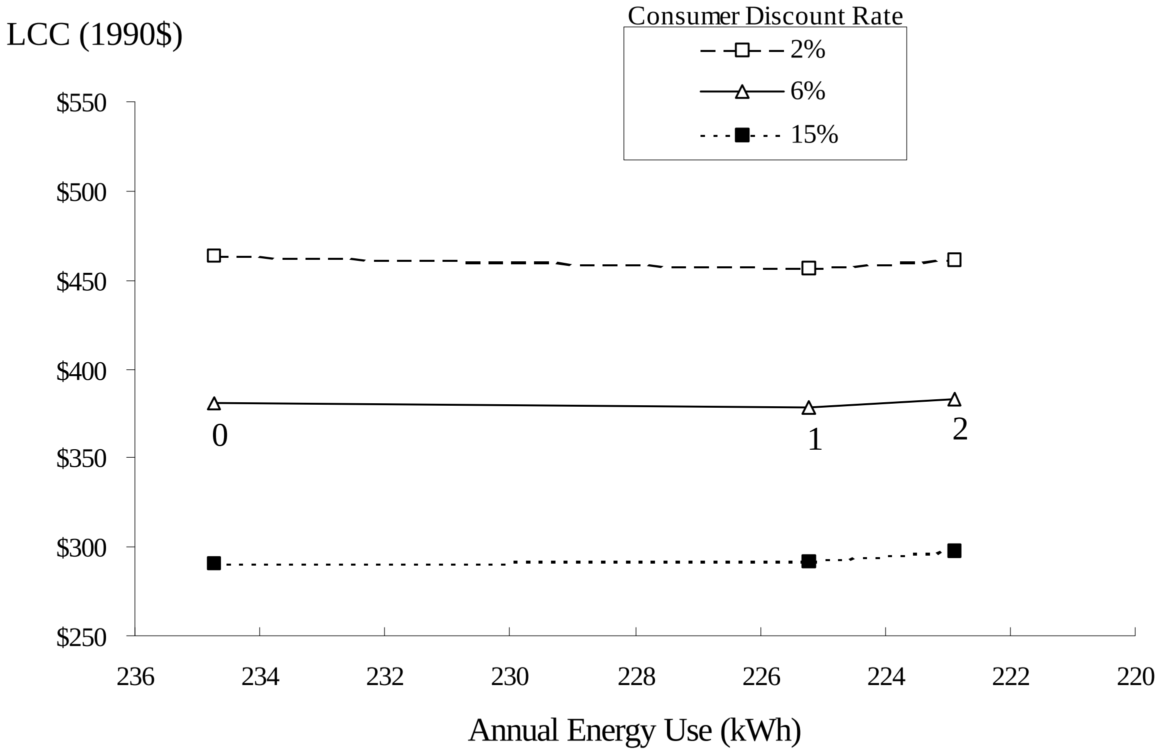

Table 4.1 Life-Cycle Costs for Electric Cooktop, Coil Element

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use *(kWh)*	Annual Energy Expense	Life-Cycle Costs 2%	Life-Cycle Costs 6%	Life-Cycle Costs 15%
1	0	Baseline	0.74	$179	$0	$179	$0	234.7	$18	$463	$381	$291
2,3	1	0 + Impr Contact Cond	0.77	$184	$0	$184	$0	225.2	$17	$457	$378	$292
4,5	2	1 + Reflective Surf	0.78	$191	$0	$191	$0	222.9	$17	$461	$383	$298

All dollar values in 1990$
Electricity price = 0.0772 $/kWh
Lifetime = 19 years.

Figure 4.2 Life-Cycle Costs for Electric Cooktops, Smooth Element

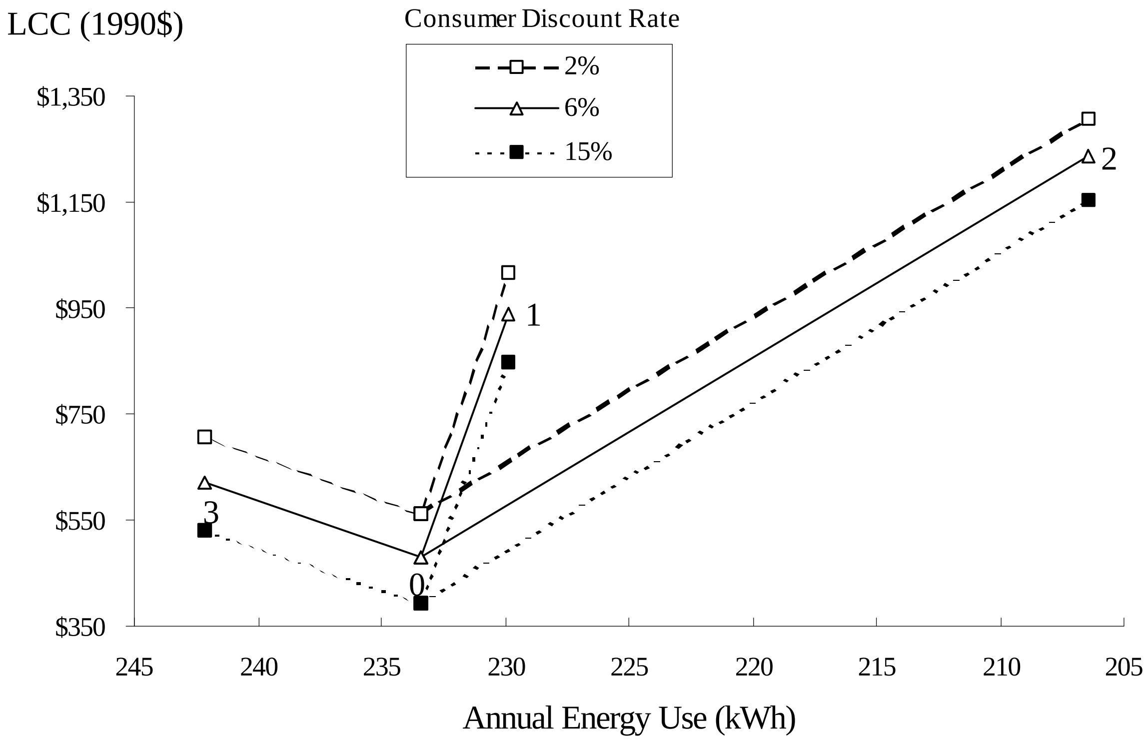

Table 4.2 Life-Cycle Costs for Electric Cooktops, Smooth Element

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use *(kWh)*	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
1,2,3,4	0	Baseline	0.74	$280	$0	$280	$0	233.38	$18	$562	$481	$391
	1	0 + Halogen	0.75	$739	$0	$739	$0	229.84	$18	$1,017	$937	$849
5	2	0 + Induction	0.84	$1,057	$0	$1,057	$0	206.39	$16	$1,307	$1,235	$1,156
	3	0 + Radiant	0.71	$413	$0	$413	$0	242.16	$19	$707	$622	$529

All dollar values in 1990$
Electricity price = 0.0772 $/kWh
Lifetime = 19 years.

Figure 4.3 Life-Cycle Costs for Gas Cooktop

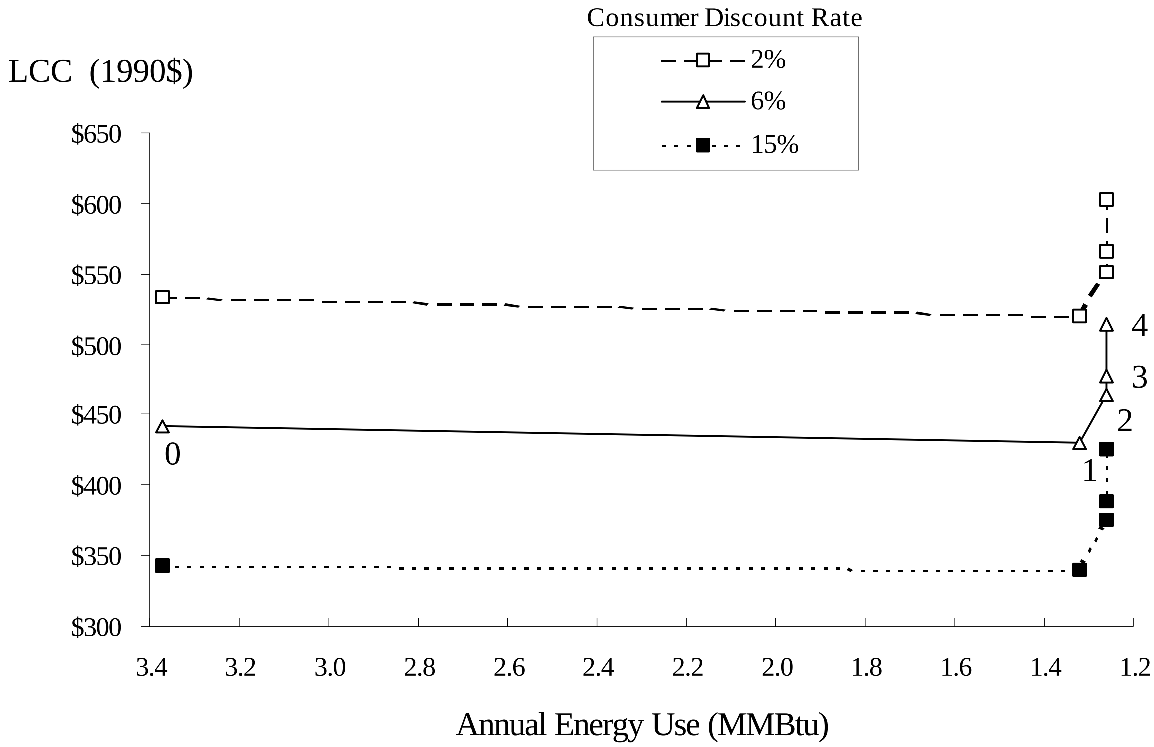

Table 4.3 Life-Cycle Costs for Gas Cooktop

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use Gas (MMBtu)	Electric (kWh)	Total (MMBtu)	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
1,2	0	Baseline	0.16	$219	$0	$219	$0	3.37	0.000	3.37	$20	$533	$442	$343
3,4	1	0 + Electronic Ign	0.40	$245	$22.50	$267	$7	1.32	0.000	1.32	$8	$525	$436	$346
	2	1 + Sealed Burner	0.42	$282	$22.50	$305	$7	1.26	0.000	1.26	$7	$557	$469	$381
5	3	2 + Reflec Surf	0.42	$296	$22.50	$318	$7	1.26	0.000	1.26	$7	$571	$483	$394
	4	3 + Tstat Burners	0.42	$333	$22.50	$356	$7	1.26	0.000	1.26	$7	$608	$520	$432

All dollar values in 1990$
Design options eliminated: Reduce Burner Excess Air (insufficient data to support design option)
Electricity price = 0.0772 $/kWh , Gas price = 5.94 $/MMBtu
Lifetime = 19 years.

Figure 4.4 Life-Cycle Costs for Electric Oven, non Self-Cleaning

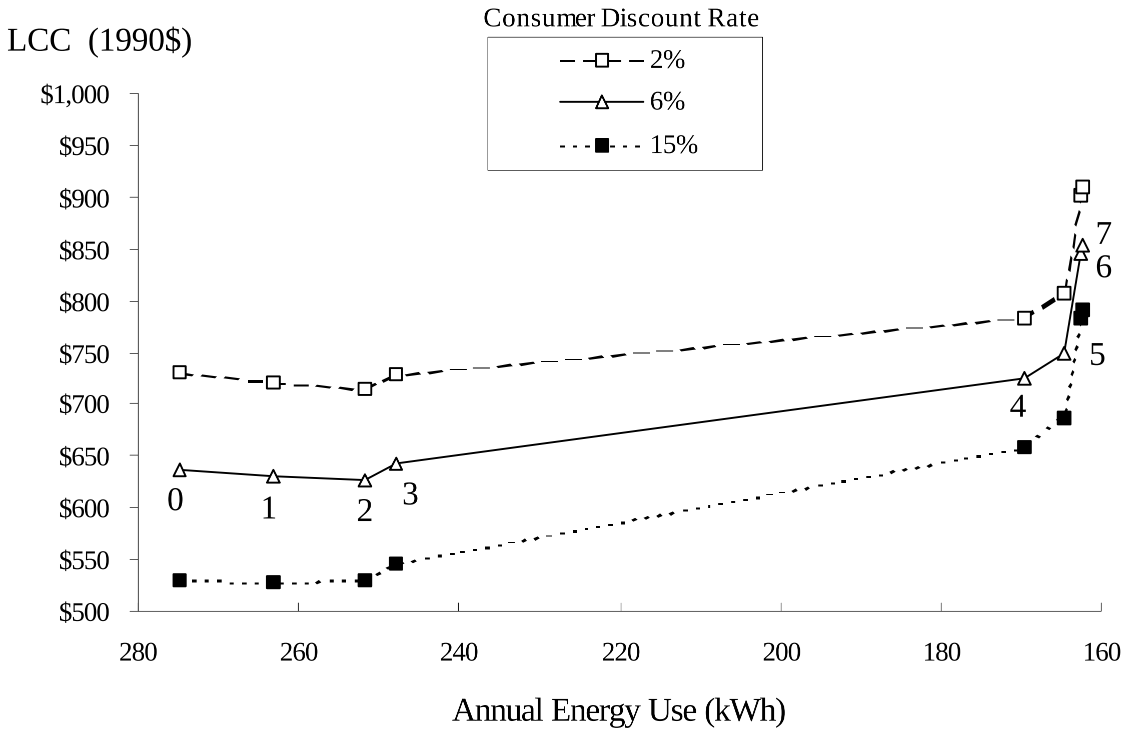

Table 4.4 Life-Cycle Costs for Electric Oven, non Self-Cleaning

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use *(kWh)*	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
	0	baseline	0.11	$399	$0	$399	$0	274.94	$21	$732	$636	$531
1	1	0 + Reduced Vent Rate	0.11	$403	$0	$403	$0	263.23	$20	$721	$629	$529
2	2	1 + Impr_insul	0.12	$410	$0	$410	$0	251.78	$19	$715	$627	$531
3	3	2 + Impr Seals	0.12	$428	$0	$428	$0	247.96	$19	$728	$641	$546
4	4	3 + Biradiant Oven	0.17	$578	$0	$578	$0	169.57	$13	$783	$724	$659
	5	4 + Separator	0.18	$607	$0	$607	$0	164.60	$13	$806	$749	$686
	6	5+ Forced Convection	0.18	$705	$0	$705	$0	162.70	$13	$902	$845	$783
5	7	6 + Reduced Cond Losses	0.18	$713	$0	$713	$0	162.42	$13	$910	$853	$791

All dollar values in 1990$
Design options eliminated: remove oven door window (utility); reflective surf (utility); reduced thermal mass (safety, utility); added insulation (utility)
Electricity price = 0.0772$/kWh
Lifetime = 19 years.

Figure 4.5 Life-Cycle Costs for Electric Oven, Self-Cleaning

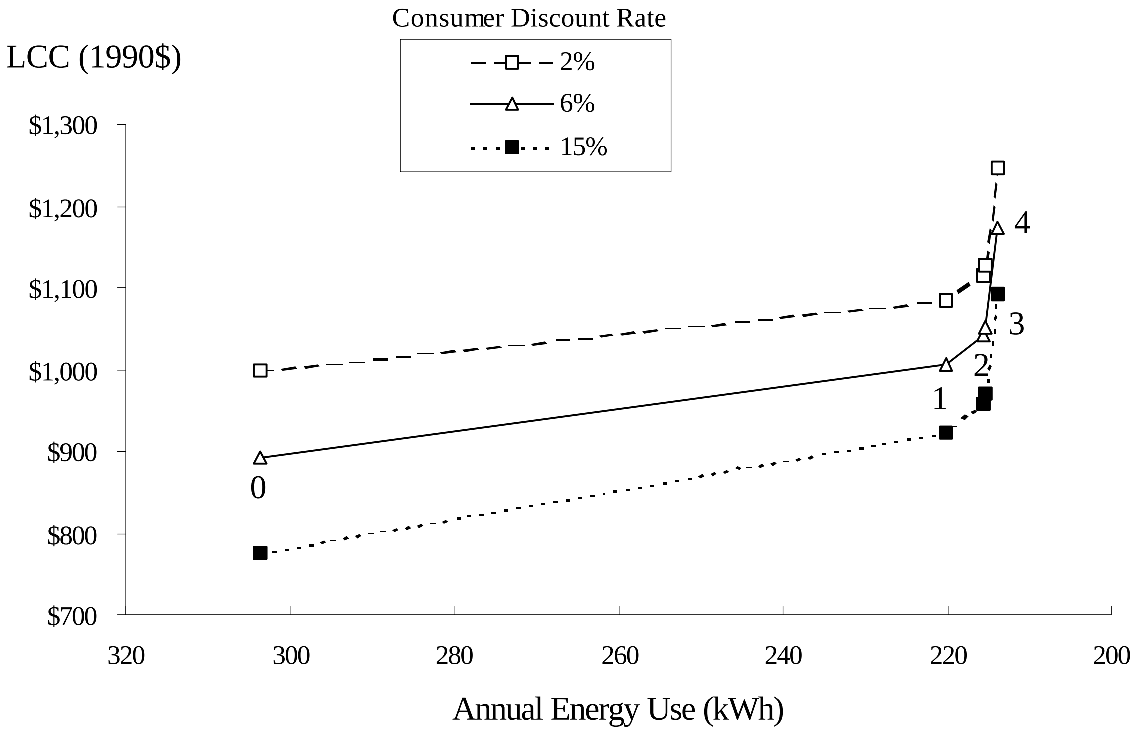

Table 4.5 Life-Cycle Costs for Electric Oven, Self-Cleaning

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use *(kWh)*	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
1,2,3	0	baseline	0.10	$630	$0	$630	$0	303.72	$23	$998	$892	$775
4	1	0 + Biradiant Oven	0.13	$817	$0	$817	$0	220.02	$17	$1,084	$1,007	$923
	2	1 + Separator	0.14	$855	$0	$855	$0	215.54	$17	$1,116	$1,041	$958
	3	2 + Reduced Cond Losses	0.14	$868	$0	$868	$0	215.27	$17	$1,128	$1,053	$971
5	4	3 + Forced Convection	0.14	$989	$0	$989	$0	213.73	$16	$1,248	$1,173	$1,091

All dollar values in 1990$
Design options eliminated: remove oven door window (utility); reflective surf (utility); reduced thermal mass (safety, utility); added insulation (utility)
Electricity price = 0.0772 $/kWh
Lifetime = 19 years.

Figure 4.6 Life-Cycle Costs for Gas Oven, non Self-Cleaning

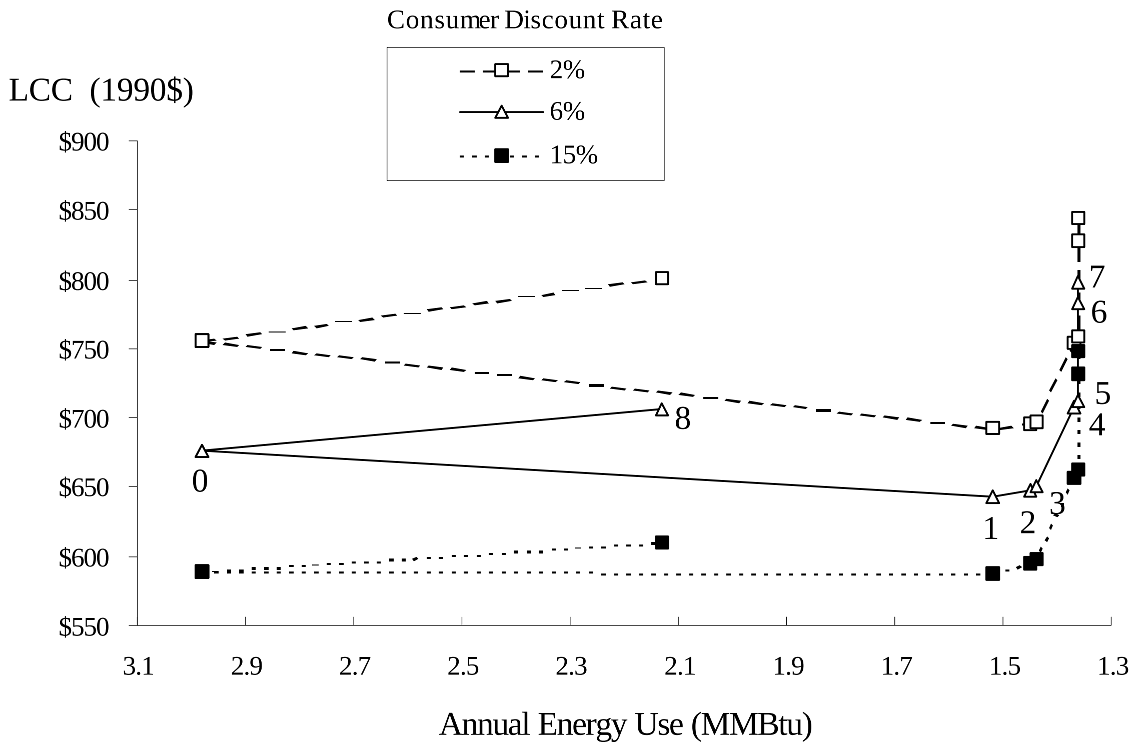

Table 4.6 Life-Cycle Costs for Gas Oven, non Self-Cleaning

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use Gas *(MMBtu)*	Electric *(kWh)*	Total *(MMBtu)*	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
1,2	0	Baseline	0.030	$479	$0	$479	$0	2.98	0.00	2.98	$18	$757	$677	$589
3	1	0 + Electric Glo-bar Ignition	0.058	$503	$22.50	$525	$0	1.41	34.16	1.52	$11	$698	$648	$594
	2	1 + Impr insul	0.061	$512	$22.50	$535	$0	1.34	34.16	1.45	$11	$701	$653	$601
4	3	2 + Impr Seals	0.062	$516	$22.50	$538	$0	1.32	34.16	1.44	$10	$703	$655	$603
	4	3 + Forced Convection	0.065	$577	$22.50	$600	$0	1.24	37.08	1.37	$10	$760	$714	$663
	5	4 + Reduced Vent Rate	0.065	$582	$22.50	$605	$0	1.23	37.08	1.36	$10	$764	$718	$668
5	6	5 + Separator	0.065	$652	$22.50	$674	$0	1.23	37.08	1.36	$10	$833	$787	$737
	7	6 + Reduced Conduction Losses	0.065	$668	$22.50	$691	$0	1.23	37.08	1.36	$10	$850	$804	$754
	8	0+ Electronic Spark Ignition	0.058	$507	$22.50	$530	$7	1.52	0.00	1.52	$9	$806	$711	$615

All dollar values in 1990$
Design options eliminated: remove oven door window (utility); reduced thermal mass (safety, utility); reflecetive surf (utility); added insulation (utility)
Electricity price = 0.0772 $/kWh , Gas price = 5.94 $/MMBtu
Lifetime = 19 years.

Figure 4.7 Life-Cycle Costs for Gas Oven, Self-Cleaning

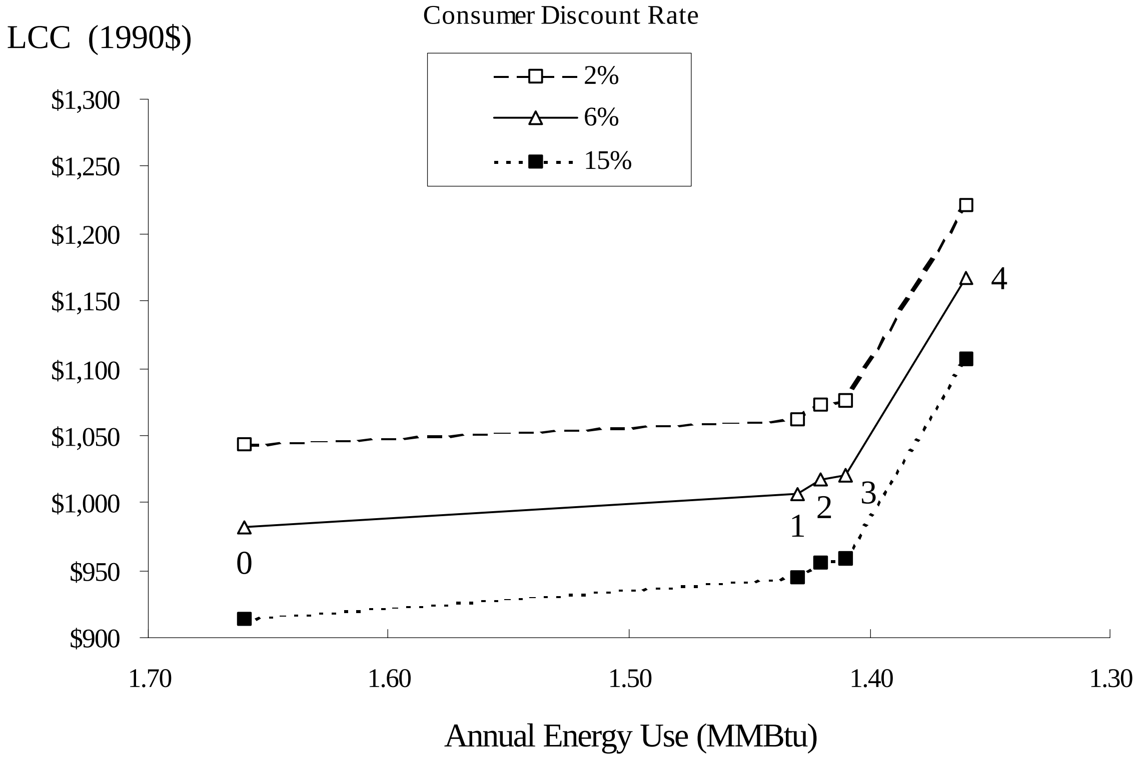

Table 4.7 Life-Cycle Costs for Gas Oven, Self-Cleaning

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use: Gas *(MMBtu)*	Annual Energy Use: Electric *(kWh)*	Annual Energy Use: Total *(MMBtu)*	Annual Energy Expense	Life-Cycle Costs: 2%	Life-Cycle Costs: 6%	Life-Cycle Costs: 15%
1,2,3,4	0	Baseline	0.054	$829	$0	$829	$0	1.43	66.68	1.66	$14	$1,043	$981	$914
	1	0 + Forced Conv	0.062	$865	$0	$865	$0	1.19	69.70	1.43	$12	$1,060	$1,004	$942
	2	1 + Reduced Cond Losses	0.062	$879	$0	$879	$0	1.18	69.70	1.42	$12	$1,073	$1,017	$956
	3	2 + Improved Seals	0.063	$882	$0	$882	$0	1.18	69.70	1.41	$12	$1,077	$1,021	$959
5	4	3 + Separator	0.065	$1,033	$0	$1,033	$0	1.12	69.70	1.36	$12	$1,222	$1,167	$1,107

All dollar values in 1990$

Design options eliminated: remove oven door window (utility); reflective surfaces(utility); reduced thermal mass(safety, utility); added insulation (utility)

Electricity price = 0.0772 $/kWh , Gas price = 5.94 $/MMBtu

Lifetime = 19 years.

Table 4.8 Life-Cycle Costs for Microwave Oven

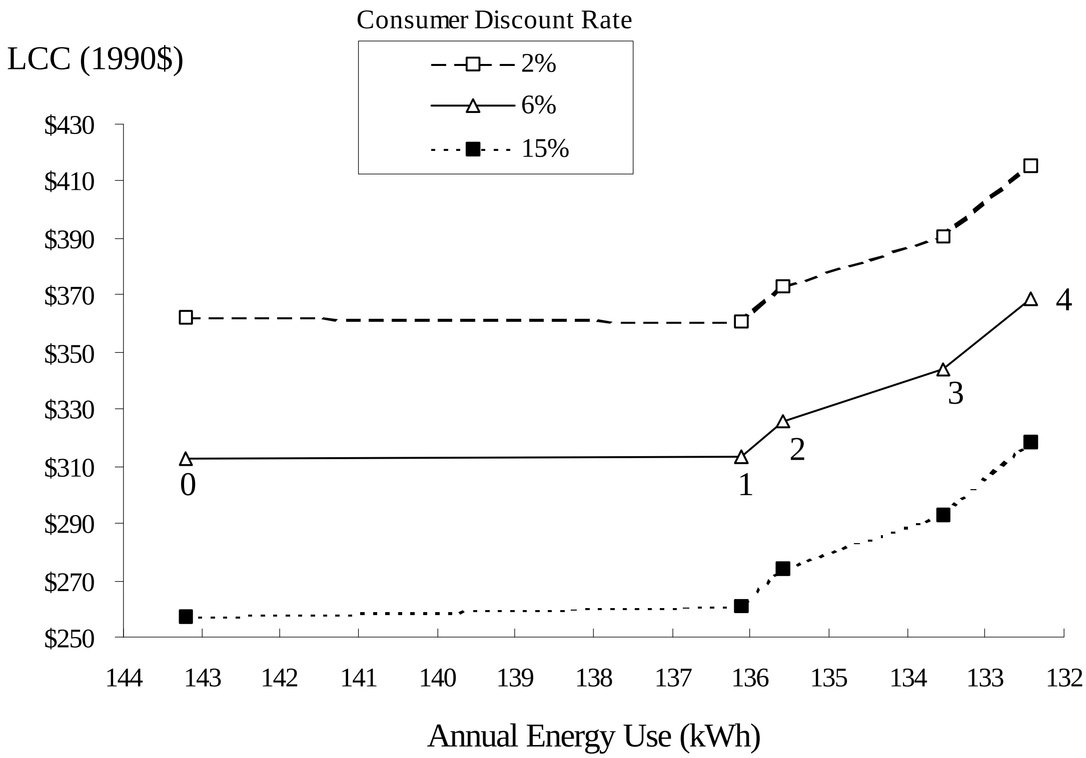

Table 4.8 Life-Cycle Costs for Microwave Ovens

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maintenance Cost (@6%)	Annual Energy Use *(kWh)*	Annual Energy Expense	Life-Cycle Costs 2%	6%	15%
1,2,3,4	0	baseline	0.557	$189	$0	$189	$0	143.20	$11	$362	$312	$258
	1	0 + Eff power source	0.586	$196	$0	$196	$0	136.11	$11	$361	$313	$261
	2	1 + Eff fan	0.588	$209	$0	$209	$0	135.58	$10	$373	$326	$274
	3	2 + Eff magnetron	0.597	$229	$0	$229	$0	133.54	$10	$391	$344	$293
5	4	3 + Reflec surf	0.602	$255	$0	$255	$0	132.43	$10	$415	$369	$318

All dollar values in 1990$
Design options eliminated: Efficient wave guide
Electricity price = 0.0772 $/kWh
Lifetime = 10 years.

4.1.3 LCC and Payback for Gas Ranges

Based on comments received during the NOPR review, an analysis of gas ranges has been completed that more closely represents typical consumer purchases. Volume 2, Chapter 1, Section 1.6 of this TSD presents an engineering analysis that combines the individual design options for a gas cooktop and a gas oven into the more familiar gas range. The primary purpose of this analysis was to study the effect on life-cycle costs of installing a pilotless ignition range rather than both an oven and a cooktop with pilotless ignitions in a home that does not have an outlet readily available.

This analysis assumes a national average of $22.50 for the installation of a single electrical outlet (see Section 1.3.3 for further details on this assumption); the installation of two outlets would be $45.00. A consumer installing a gas oven and a gas cooktop in a home that does not have an electrical outlet readily available would require the addition of two electrical outlets. In contrast, a consumer installing a gas range would need only one outlet. According to recent shipment data, gas ranges account for approximately 87% of the gas cooking products shipped (3). Consequently, many customers benefit from the reduced installation cost associated with gas ranges.

Table 4.9 presents the results of the gas range analysis. Figure 4.9 shows that many of the design options for gas ranges have LCC values that are less than the baseline LCC. Payback periods are also noted in the figure to demonstrate the relative affect of each option on the consumer.

Figure 4.9 Life-Cycle Costs for Gas Ranges with Installation Costs of $22.50 (@ 6% real)

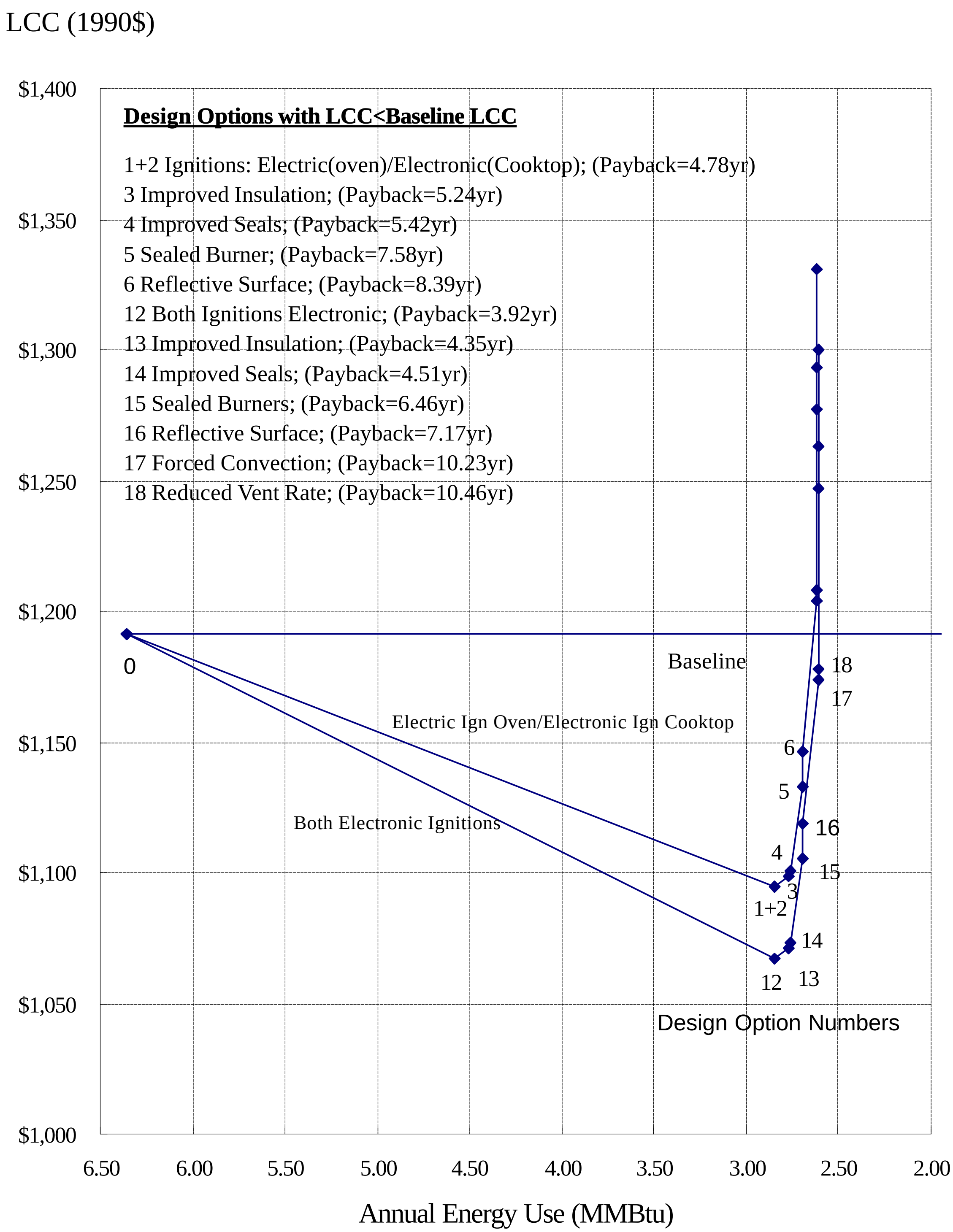

Table 4.9 Life-Cycle Costs and Payback Periods for Gas Cooktops, Ovens, & Ranges

For Gas Cooktops

Efficiency Level	Design No.	Design Option	EF	Retail Price	Installation Cost	Installed Consumer Cost	Annual Maint. Cost (@6%)	Annual Energy Use Gas *(MMBtu)*	Electric *(kWh)*	Total *(MMBtu)*	Annual Energy Expense	Cumul. Payback Period (years)	Life-Cycle Costs 2%	6%	15%
1,2	0	Baseline	0.156	$219	$0.00	$219	$0.00	3.37	0	3.37	$23	NA	$586	$480	$364
3,4	1	0 + Electronic Ign	0.399	$244	$22.50	$267	$7.25	1.32	0	1.32	$9	6.8	$524	$450	$368
	2	1 + Sealed Burner	0.42	$281	$22.50	$304	$7.25	1.26	0	1.26	$9	11.4	$555	$482	$403
5	3	2 + Reflec Surf	0.42	$295	$22.50	$317	$7.25	1.26	0	1.26	$9	13.2	$568	$495	$416
	4	3 + Tstat Burners	0.42	$332	$22.50	$354	$7.25	1.26	0	1.26	$9	18.2	$605	$532	$453

For Gas Ovens, non Self-Cleaning

1,2	0	Baseline	0.03	$479	0	$479	0	2.98	0	2.98	$21	NA	$804	$711	$608
3	1	0 + Electric Glo-bar Ignition	0.058	$504	$22.50	$527	0	1.41	34.16	1.52	$13	5.8	$724	$667	$605
	2	1 + Impr insul	0.061	$514	$22.50	$536	0	1.34	34.16	1.45	$12	6.6	$726	$671	$611
4	3	2 + Impr Seals	0.062	$517	$22.50	$539	0	1.32	34.16	1.44	$12	6.9	$728	$673	$614
	4	3 + Forced Convection	0.065	$578	$22.50	$601	0	1.24	37.08	1.37	$12	13.4	$784	$731	$673
	5	4 + Reduced Vent Rate	0.065	$583	$22.50	$605	0	1.23	37.08	1.36	$12	13.9	$788	$735	$678
5	6	5 + Separator	0.065	$652	$22.50	$675	0	1.23	37.08	1.36	$12	21.5	$857	$804	$747
	7	6 + Reduced Cond. Losses	0.065	$668	$22.50	$691	0	1.23	37.08	1.36	$12	23.3	$873	$821	$763
	8	0+ Electronic Spark Ignition	0.058	$516	$22.50	$538	7.25	1.52	0	1.52	$11	20.4	$818	$737	$649

For Gas Ranges

1,2	0	Baseline	NA	$698	0	$698	0	6.35	0	6.35	$44	NA	$1,391	$1,191	$972
3	1+2	0+Ign:Electric(Oven)/IID(Top)	NA	$748	$22.50	$771	7.25	2.73	34.16	2.85	$22	4.8	$1,226	$1,095	$951
4	3	1+2+ Impr Insul	NA	$758	$22.50	$780	7.25	2.66	34.16	2.77	$21	5.2	$1,228	$1,099	$957
4	4	3+ Impr Seals	NA	$761	$22.50	$783	7.25	2.64	34.16	2.76	$21	5.4	$1,229	$1,101	$960
5	5	4+ Sealed Burner	NA	$798	$22.50	$821	7.25	2.58	34.16	2.7	$21	7.6	$1,260	$1,133	$994
5	6	5+ Reflec Surface	NA	$811	$22.50	$834	7.25	2.58	34.16	2.69	$21	8.4	$1,273	$1,146	$1,007
5	7	6+ Forced Convect	NA	$873	$22.50	$895	7.25	2.5	37.08	2.62	$20	11.9	$1,329	$1,204	$1,067
5	8	7+ Reduced Vent Rate	NA	$878	$22.50	$900	7.25	2.49	37.08	2.62	$20	12.2	$1,333	$1,208	$1,071
5	9	8+ Separator	NA	$947	$22.50	$969	7.25	2.49	37.08	2.62	$20	16.4	$1,402	$1,277	$1,140
5+	10	9+ Reduc Cond Loss	NA	$963	$22.50	$985	7.25	2.49	37.08	2.62	$20	17.4	$1,418	$1,293	$1,157
5+	11	10+ Tstat Burners	NA	$1,000	$22.50	$1,023	7.25	2.49	37.08	2.62	$20	19.6	$1,455	$1,331	$1,194
3	12	0 + Both IID Ign's (Oven&Ctop)	NA	$743	$22.50	$765	7.25	2.85	0	2.85	$20	3.9	$1,189	$1,067	$933
4	13	12+ Impr Insul	NA	$752	$22.50	$775	7.25	2.77	0	2.77	$19	4.4	$1,191	$1,071	$939
4	14	13+ Impr Seals	NA	$756	$22.50	$778	7.25	2.76	0	2.76	$19	4.5	$1,193	$1,073	$942
5	15	14+ Sealed Burner	NA	$793	$22.50	$816	7.25	2.69	0	2.69	$19	6.5	$1,223	$1,106	$977
5	16	15+ Reflec Surface	NA	$806	$22.50	$829	7.25	2.69	0	2.69	$19	7.2	$1,236	$1,119	$990
5	17	16+ Forced Convect	NA	$868	$22.50	$890	7.25	2.61	0	2.61	$18	10.2	$1,288	$1,174	$1,048
5	18	17+ Reduced Vent Rate	NA	$872	$22.50	$895	7.25	2.61	0	2.61	$18	10.5	$1,293	$1,178	$1,052
5	19	18+ Separator	NA	$941	$22.50	$964	7.25	2.61	0	2.61	$18	14.1	$1,361	$1,247	$1,121
5+	20	19+ Reduc Cond Loss	NA	$958	$22.50	$980	7.25	2.6	0	2.6	$18	15.0	$1,378	$1,263	$1,137
5+	21	20+ Tstat Burners	NA	$995	$22.50	$1,017	7.25	2.6	0	2.6	$18	17.0	$1,415	$1,300	$1,174

4.2 LCC SENSITIVITY ANALYSIS

The national LCC results were tested for sensitivity data by varying assumptions about energy and equipment prices for representative product classes. The results of this analysis should be compared to the first set of tables in Section 4.1.

Low and high energy prices were defined as the minimum and maximum, respectively, of states' energy prices. State energy prices for 1992 (4), relative to the national average, were applied to the projected 1998 national average price from the *Annual Energy Outlook 1995* (5) to obtain state prices for 1998. (This represents a wider range of prices than analyzed in previous analyses based on the average across Census regions.)

Low and high equipment prices were defined as one standard deviation below and above, respectively, the equipment prices used elsewhere in this chapter (from the Engineering Analysis). Note that the uncertainty in the baseline price is a percent of the total price, while the uncertainty in the price of other designs is applied to the incremental price of that design.

The following sensitivity cases were analyzed:

(1) low (state) energy prices;
(2) high equipment prices;
(3) low (state) energy prices and high equipment prices;
(4) high (state) energy prices;
(5) low equipment prices; and
(6) high (state) energy prices and low equipment prices;

Figures and Tables 4.10 - 4.14 summarize the results of the sensitivity analyses. These figures tables include:

- graphs of highest and lowest LCC sensitivity, and reference case;
- LCC data for all sensitivity cases, and a listing of the number of sensitivity cases for which each design option is the minimum LCC.

Figure 4.10 Life-Cycle Cost Sensitivity Range for Electric Cooktop, Coil Element

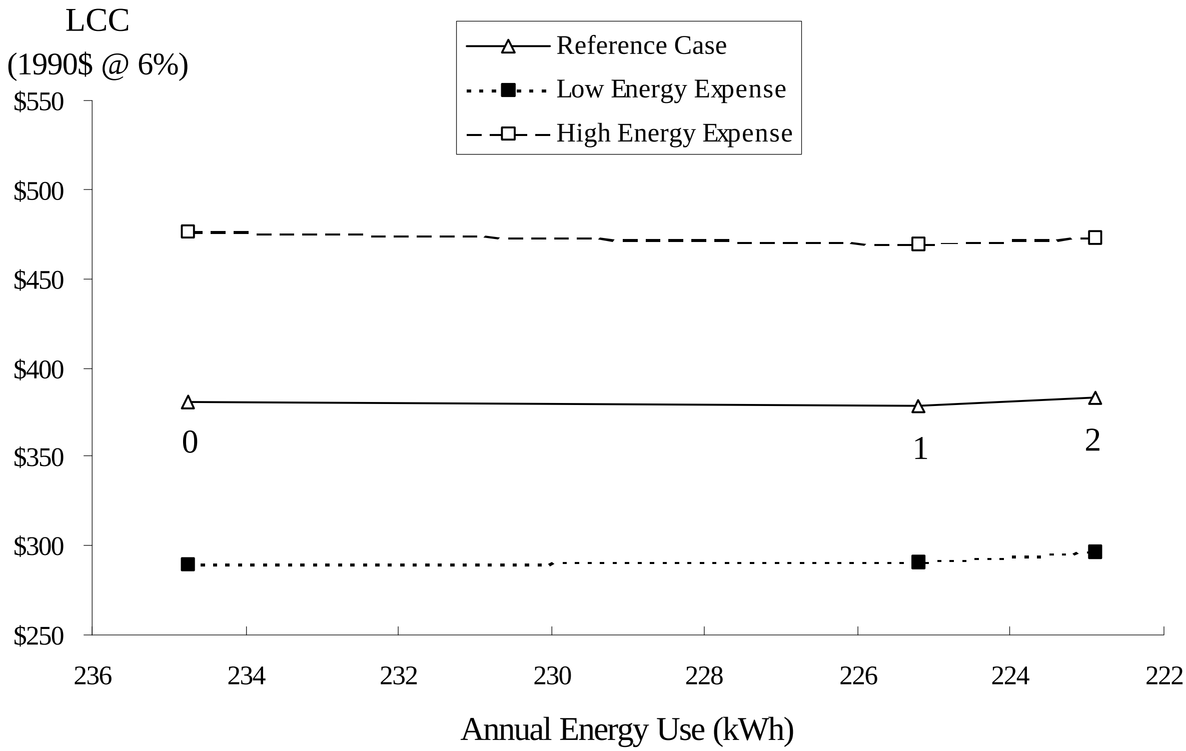

Table 4.10 Summary of LCC Sensitivites for Electric Cooktop, Coil Element

Efficiency Level	Design No.	Sensitivity Scenarios: Reference	1	2	3	4	5	6	Number of times as min. LCC
1	0	$381.12	$289.96	$434.94	$343.78	$476.52	$327.48	$422.89	2
2,3	1	$377.92	$290.46	$433.11	$345.65	$469.44	$322.26	$413.79	4
4,5	2	$382.93	$296.37	$441.87	$355.32	$473.52	$323.08	$413.67	1

Minimum LCC values are noted with a heavy border for each sensitivity scenario
All values in 1990$ @ 6% real

Figure 4.11 Life-Cycle Cost Sensitivity Range for Gas Cooktop

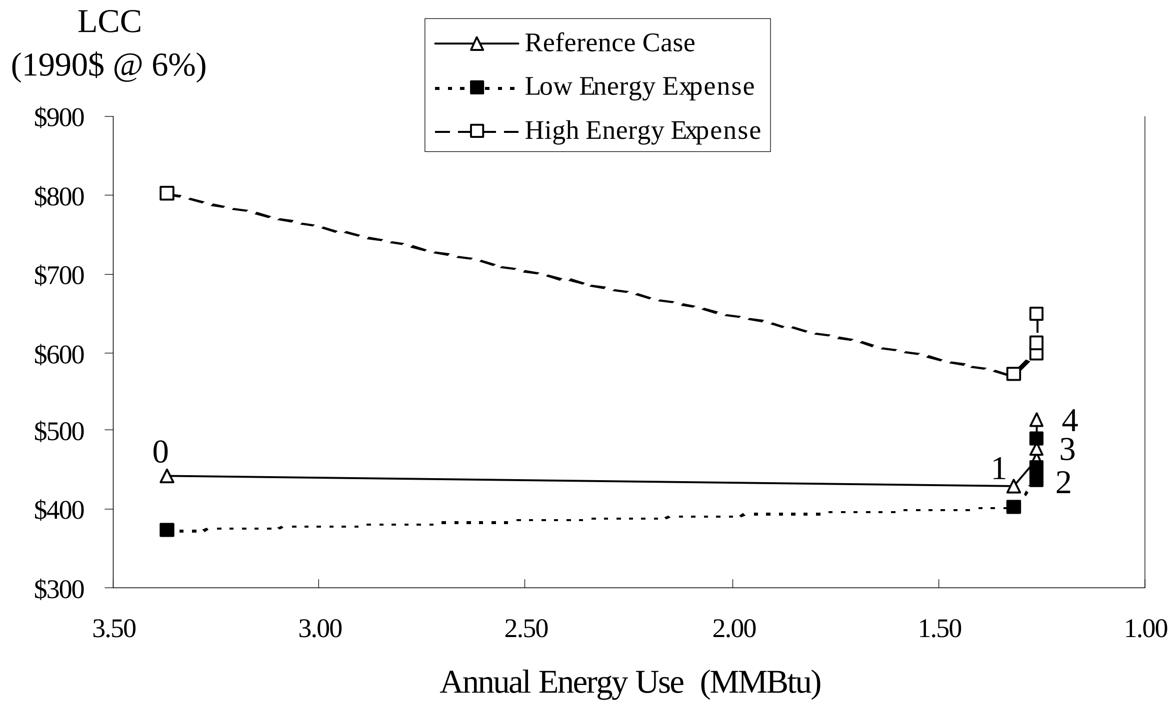

Table 4.11 Summary of LCC Sensitivites for Gas Cooktop

Efficiency Level	Design No.	Sensitivity Scenarios: Reference	1	2	3	4	5	6	Number of times as min. LCC
1,2	0	$442.08	$374.87	$463.96	$396.75	$802.01	$420.20	$780.13	2
3,4	1	$435.63	$409.30	$435.37	$409.04	$576.61	$389.47	$530.45	5
	2	$469.31	$444.18	$477.27	$452.14	$603.89	$414.48	$549.05	
5	3	$482.56	$457.43	$498.07	$472.94	$617.14	$419.90	$554.47	
	4	$520.02	$494.89	$542.67	$517.54	$654.60	$449.42	$583.99	

Minimum LCC values are noted with a heavy border for each sensitivity scenario.
All values in 1990$ @ 6% real

Figure 4.12 Life-Cycle Cost Sensitivity Range for Electric Oven, non Self-Cleaning

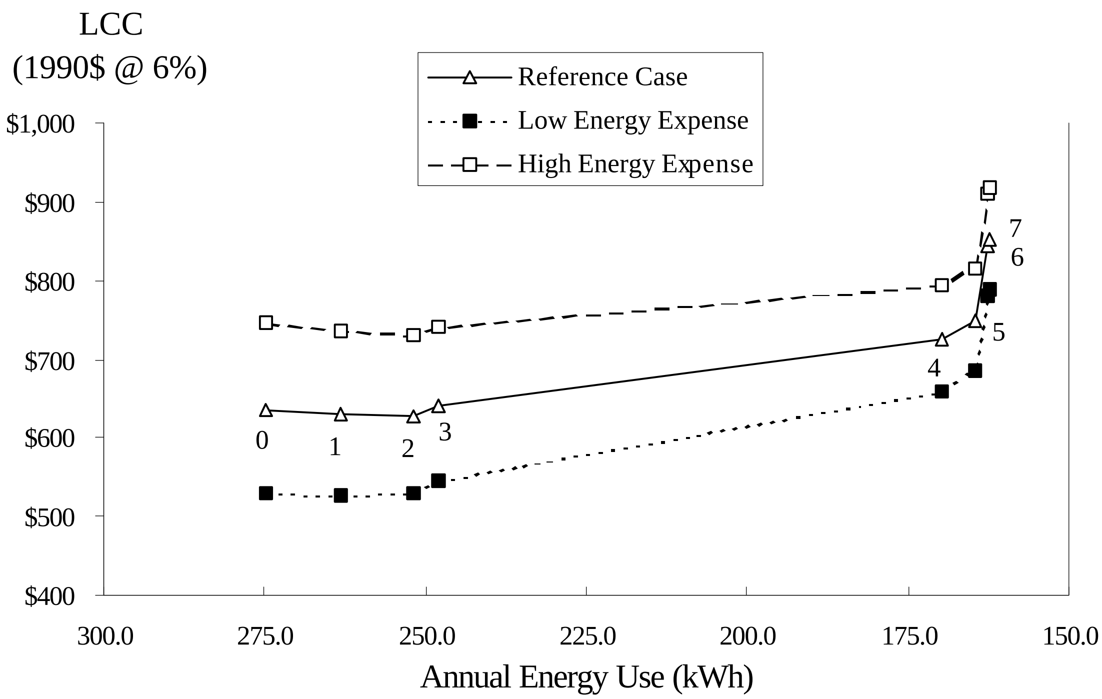

Table 4.12 Summary of LCC Sensitivities for Electric Oven, non Self-Cleaning

Efficiency Level	Design No.	Sensitivity Scenarios: Reference	1	2	3	4	5	6	Number of times as min. LCC
	0	$635.82	$529.05	$715.63	$608.86	$747.55	$556.00	$667.74	1
1	1	$629.20	$526.98	$712.28	$610.06	$736.18	$545.24	$652.22	2
2	2	$626.87	$529.10	$714.37	$616.59	$729.20	$539.00	$641.33	3
3	3	$641.33	$545.04	$732.91	$636.62	$742.11	$549.24	$650.01	
4	4	$723.84	$657.99	$893.77	$827.92	$792.75	$551.44	$620.36	1
	5	$748.83	$684.91	$933.61	$869.69	$815.72	$561.34	$628.24	
	6	$844.77	$781.59	$1079.10	$1015.92	$910.90	$607.10	$673.22	
5	7	$853.00	$789.93	$1092.13	$1029.05	$919.01	$610.48	$676.48	

Minimum LCC values are noted with a heavy border for each sensitivity scenario.
All values in 1990$ @ 6% real

Figure 4.13 Life-Cycle Cost Sensitivity Range for Gas Oven, non Self-Cleaning

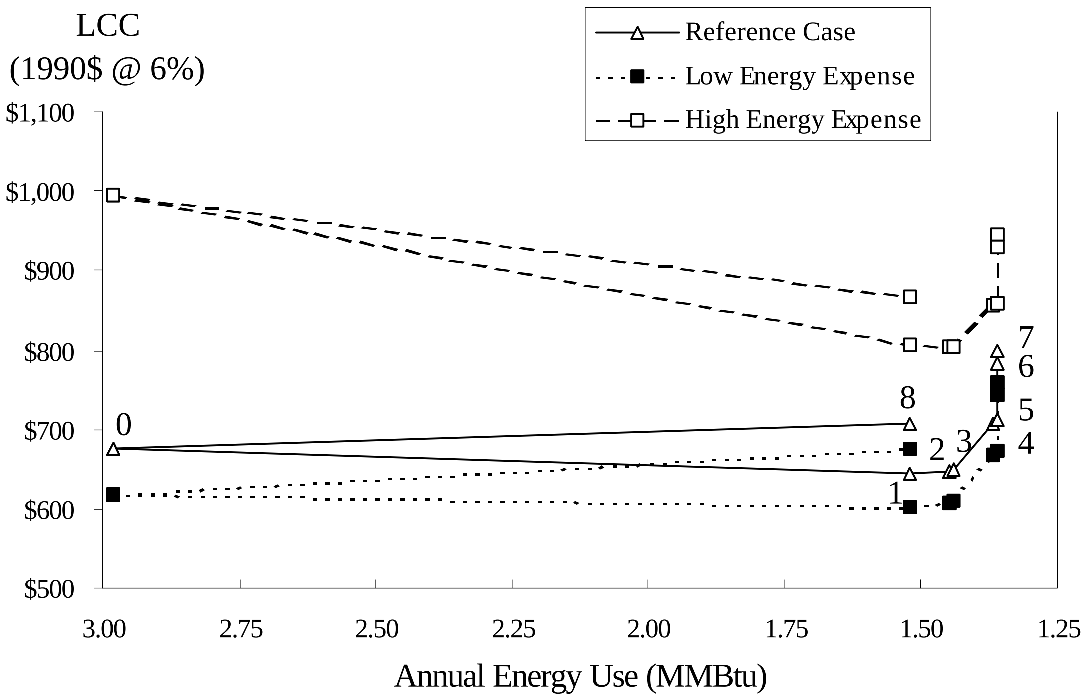

Table 4.13 Summary of LCC Sensitivities for Gas Oven, non Self-Cleaning

Efficiency Level	Design No.	Sensitivity Scenarios: Reference	1	2	3	4	5	6	Number of times as min. LCC
1,2	0	$676.93	$617.50	$796.80	$737.37	$995.21	$557.06	$875.34	
3	1	$642.63	$601.25	$745.59	$704.20	$807.11	$508.14	$672.62	5
	2	$647.61	$607.62	$754.96	$714.97	$804.61	$508.43	$665.43	
4	3	$649.67	$610.08	$757.84	$718.25	$804.54	$509.63	$664.49	2
	4	$708.51	$669.39	$848.33	$809.20	$856.02	$536.30	$683.80	
	5	$712.59	$673.66	$856.70	$817.77	$859.03	$536.03	$682.46	
5	6	$781.92	$742.99	$996.34	$957.42	$928.36	$534.62	$681.06	
	7	$798.42	$759.49	$1020.52	$981.59	$944.86	$543.06	$689.50	
	8	$705.71	$675.40	$817.19	$786.87	$868.05	$577.57	$739.91	

Minimum LCC values are noted with a heavy border for each sensitivity scenario.
All values in 1990$ @ 6% real

Figure 4.14 Life-Cycle Cost Sensitivity Range for Microwave Oven

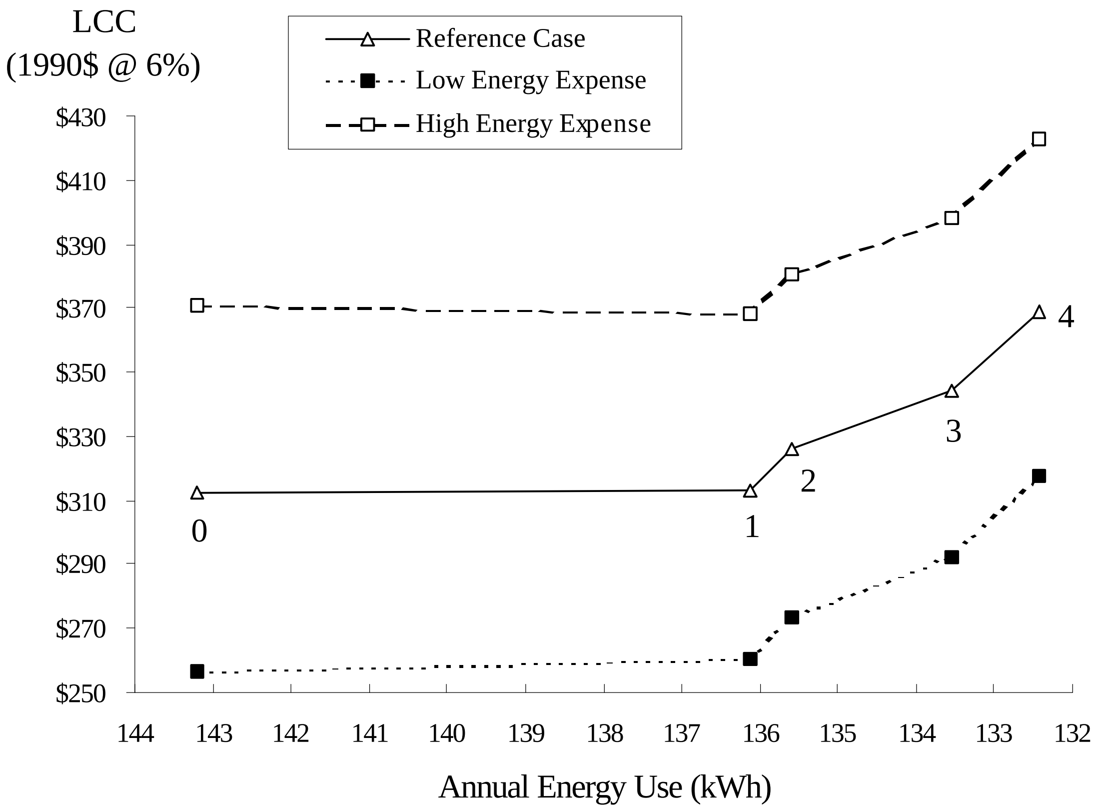

Table 4.14 Summary of LCC Sensitivities for Microwave Oven

Efficiency Level	Design No.	Sensitivity Scenarios: Reference	1	2	3	4	5	6	Number of times as min. LCC
1,2,3,4	0	$312.35	$256.72	$350.15	$294.52	$370.58	$274.55	$332.78	4
	1	$313.25	$260.37	$352.30	$299.43	$368.59	$273.95	$329.29	3
	2	$325.79	$273.12	$367.22	$314.55	$380.92	$283.74	$338.87	
	3	$344.03	$292.15	$389.63	$337.75	$398.33	$298.09	$352.39	
5	4	$369.08	$317.63	$419.48	$368.03	$422.92	$317.68	$371.52	

Minimum LCC values are noted with a heavy border for each sensitivity scenario
All values in 1990$ @ 6% real

4.3 CHANGE IN LIFE-CYCLE COSTS DUE TO ENERGY EFFICIENCY LEVELS

The impact of energy efficiency levels is calculated as the difference in LCC, base case minus efficiency levels case. If the LCC difference is greater than zero (positive savings), the efficiency level provides a net decrease in expenses to the consumer. That is, the present value of decreased operating expenses offsets the increased purchase price. Conversely, if the LCC difference is negative, the efficiency level causes a net increase in expenses to the consumer.

Tables 4.15 to 4.22 show the calculation of LCC differences, payback, and CCE. The tables are composed of several parts. Part "a" summarizes for each design option the installed consumer cost, annual electric use, and operating expense; LCC (at 6% consumer discount rate); and the distribution of units sold in 1999, according to the base case forecast. Part "b" applies the weights from the distributions listed in the last column of part "a", to the values in each preceding column in order to obtain weighted average values. Finally, Part "c" shows the resulting LCC differences, PBPs, and CCE. In Part "c", PBPs for non-microwave ovens and cooktops are presented which are based upon energy use data determined both from the proposed DOE test procedure and recent field measurements. As discussed in Chapter 1 (Engineering Analysis), recent field data indicates that the annual use of non-microwave ovens and cooktops is approximately 12-17% lower than that determined with proposed DOE test procedure calculations. Because the field data indicates lower energy use, "field-based" PBPs are typically greater than those determined with the proposed test procedure.

4.3.1 Data Inputs for Change in LCC

The data required for calculating change in LCC are listed in Section 4.1.1. In addition, the calculation requires that a distribution of design options is projected (by LBNL-REM) for the base case. Only those designs that are eliminated by the efficiency level are included in the calculation of impacts. Consumers whose base case choice is eliminated by energy efficiency levels are assumed to purchase the design option corresponding to the minimum compliance with the efficiency level.

4.3.2 Results for Change in LCC

Tables 4.15c through 4.22c show the LCC differences by energy efficiency level, one table for each class. The results are the weighted average of LCC differences comparing that portion of the projected distribution of designs in the base case that are less efficient than the efficiency level to the design at the efficiency level. Designs with energy consumption at or below the efficiency level are not affected by the efficiency level, so these are excluded from the calculation of impacts. These LCCs are calculated at a 6% discount rate; a higher discount rate (e.g., 15%) gives a smaller difference.

Tables 4.15c to 4.22c show lower LCCs (A positive LCC difference) for efficiency levels 1 and 2 for all applicable classes. Efficiency level 3 demonstrates a lower LCC in three of four applicable classes. Efficiency level 4 demonstrates a lower LCC in two of five applicable classes, and efficiency level 5 does not show a lower LCC in any classes.

4.4 PAYBACK PERIODS BY ENERGY EFFICIENCY LEVEL

The payback period (PBP) measures the amount of time needed to recover the additional consumer investment in increased efficiency through lower operating costs. PBP is found by solving the equation:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = O \tag{4.4}$$

for *PAY*, where PC=purchase price and OC=operating cost. In general, *PAY* is found by interpolating between the two years when the expression in Eq. 4.4 changes sign. If the operating cost is constant, the equation has the simple solution:

$$PAY = -\frac{\Delta PC}{\Delta OC} \tag{4.5}$$

Numerically, the PBP is the ratio of the increase in purchase (and installation) price from the base to the efficiency levels cases to the decrease in annual operating expenditures (including maintenance). PBPs are expressed in years. A PBP of three years means that the increased purchase price is equal to three times the value of reduced operating expenses achieved in the year of purchase, or that the increased purchase price is recovered in approximately three years because of lower operating expenses. PBPs greater than the life of the product mean that the increased purchase price is not recovered in reduced operating expenses.

4.4.1 PBP Data Inputs

The data required for calculating PBP are listed in Section 4.1.1. In addition, the calculation requires that a distribution of design options is projected (by LBNL-REM) for the base case. Only those designs that are eliminated by the efficiency level are included in the calculation of impacts. Consumers whose base case choice is eliminated by efficiency levels are assumed to purchase the design option corresponding to the minimum compliance with the efficiency level.

4.4.2 PBP Results

The PBPs by efficiency level shown in Tables 4.15c through 4.22c are the weighted averages. They compare that portion of the projected distribution of designs in the base case which are less efficient than the efficiency level to the design at the efficiency level. Designs with energy consumption at or below the efficiency level are not affected by the efficiency level, and so are excluded from the calculation of impacts.

4.5 COST OF CONSERVED ENERGY (CCE) DUE TO ENERGY EFFICIENCY LEVELS

The CCE is the increase in purchase price amortized over the lifetime of the appliance at the consumer discount rate divided by the annual energy savings:

$$CCE = -\frac{CRF \cdot \Delta PC}{\Delta E}, \qquad \textbf{(4.6)}$$

where the capital recovery factor (*CRF = 1/PWF*) is used to annualize the capital costs. Note that although the CCE can be measured in cents per kWh, it does not depend on current or future energy prices. The consumer will benefit whenever the cost of conserved energy is less than the price of energy for that end use.

4.5.1 CCE Data Inputs

The data required for calculating CCE are listed in Section 4.1.1. In addition, the calculation requires that a distribution of design options is projected (by LBNL-REM) for the base case. Only those designs that are eliminated by the efficiency level are included in the calculation of impacts. Consumers whose base case choice is eliminated by efficiency levels are assumed to purchase the design option corresponding the minimum compliance with the efficiency level.

4.5.2 CCE Results

Tables 4.15c through 4.22c show the CCE energy (site) of the efficiency levels as compared to the base case. Note that the projected (1998) average residential electricity price is 7.94 cents per kWh (6). This is equivalent to $23.27 dollars per million Btu, where one kWh is taken as 3,412 Btu site energy.

Efficiency levels with CCEs less than projected costs of energy supply include:

All applicable classes: efficiency levels 1 and 2.

Electric cooktop, coil element: efficiency level 3.

Gas oven, non self-cleaning: efficiency level 3 and 4.

Gas cooktop: efficiency level 3 and 4.

(N/A for Electric cooktop, smooth element; Gas oven, self-cleaning; and Microwave oven.)

Efficiency levels with CCEs greater than projected costs of energy supply include:

All classes: efficiency level 5.

Electric cooktop, coil element: efficiency level 4.

Electric oven, self-cleaning: efficiency level 4.

Electric oven, non self-cleaning: efficiency levels 3 and 4.

Table 4.15a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Electric Cooktops, Coil Element

Efficiency Level	Design No.	Installed Consumer Cost	Field Elec. Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Elec. Use	PTP Operating Cost
		(1990$)	*kWh/yr*	(1990$/yr)	(1990$)		*kWh/yr*	(1990$/yr)
1	0	179.09	234.74	18.12	381.21	100.0%	283.84	21.91
2,3	1	183.90	225.21	17.39	378.00	0.0%	272.31	21.02
4,5	2	190.79	222.90	17.21	383.01	0.0%	269.52	20.81

Table 4.15b Weighted Average of Units Sold below Efficiency Levels, Electric Cooktops, Coil Element

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	179.09	179.09	179.09	179.09
Annual Operating Cost (1990 $)					
Field	N/A	18.12	18.12	18.12	18.12
Proposed Test Proc.	N/A	21.91	21.91	21.91	21.91
Life-Cycle Cost at 6% (1990 $)	N/A	381.21	381.21	381.21	381.21
Energy Use (*kWh/yr*)	N/A	234.74	234.74	234.74	234.74

Table 4.15c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Electric Cooktops, Coil Element

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	3.2	3.2	-1.8	-1.8
Payback (years)					
Field	N/A	6.5	6.5	12.8	12.8
Proposed Test Proc.	N/A	5.4	5.4	10.6	10.6
CCE *(cent/kWh)*	N/A	4.5	4.5	8.9	8.9

Table 4.16a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Electric Cooktops, Smooth Element

Efficiency Level	Design No.	Installed Consumer Cost	Field Elec. Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Elec. Use	PTP Operating Cost
		(1990$)	*kWh/yr*	(1990$/yr)	(1990$)		*kWh/yr*	(1990$/yr)
1,2,3,4	0	279.68	233.38	18.02	481.04	100.0%	282.32	21.80
	1	738.77	229.84	17.74	936.99	0.0%	278.04	21.46
5	2	1057.24	206.39	15.93	1234.79	0.0%	249.68	19.28

Table 4.16b Weighted Average of Units Sold below Efficiency Levels, Electric Cooktops, Smooth Element

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	N/A	N/A	279.68
Annual Operating Cost (1990 $)					
Field	N/A	N/A	N/A	N/A	18.02
Proposed Test Proc.	N/A	N/A	N/A	N/A	21.80
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	N/A	N/A	481.04
Energy Use (*kWh/yr*)	N/A	N/A	N/A	N/A	233.38

Table 4.16c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Electric Cooktops, Smooth Element

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	N/A	N/A	-753.8
Payback (years)					
Field	N/A	N/A	N/A	N/A	373.2
Proposed Test Proc.	N/A	N/A	N/A	N/A	308.5
CCE *(cent/kWh)*	N/A	N/A	N/A	N/A	258.2

Table 4.17a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Gas Cooktops

Efficiency Level	Design No.	Installed Consumer Cost	Field Gas Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Gas Use	PTP Operating Cost
		(1990$)	*MMBtu/yr*	(1990$/yr)	(1990$)		*MMBtu/yr*	(1990$/yr)
1,2	0	218.80	3.37	20.02	442.16	8.2%	3.89	23.09
3,4	1	267.26	1.32	7.84	435.66	91.8%	1.84	10.91
	2	304.92	1.26	7.48	469.34	0.0%	1.75	10.37
5	3	318.17	1.26	7.48	482.59	0.0%	1.74	10.36

Table 4.17b Weighted Average of Units Sold below Efficiency Levels, Gas Cooktops

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	218.80	218.80	263.30
Annual Operating Cost (1990 $)					
Field	N/A	N/A	20.02	20.02	8.84
Proposed Test Proc.	N/A	N/A	23.09	23.09	11.91
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	442.16	442.16	436.19
Energy Use (*MMBtu/yr*)	N/A	N/A	3.37	3.37	1.49

Table 4.17c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Gas Cooktops

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	6.5	6.5	-46.4
Payback (years)					
Field	N/A	N/A	4.0	4.0	40.6
Proposed Test Proc.	N/A	N/A	4.0	4.0	35.4
CCE (*$/MMBtu*)	N/A	N/A	2.1	2.1	21.0

Table 4.18a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Electric Ovens, non Self-Cleaning

Efficiency Level	Design No.	Installed Consumer Cost	Field Elec. Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Elec. Use	PTP Operating Cost
		(1990$)	*kWh/yr*	(1990$/yr)	(1990$)		*kWh/yr*	(1990$/yr)
	0	399.08	274.94	21.23	635.84	100.0%	325.97	25.16
1	1	402.55	263.23	20.32	629.75	0.0%	311.78	24.07
2	2	410.08	251.78	19.44	626.89	0.0%	297.91	23.00
3	3	427.83	247.96	19.14	641.59	0.0%	293.28	22.64
4	4	577.83	169.57	13.09	724.07	0.0%	198.31	15.31
	5	607.10	164.60	12.71	748.79	0.0%	192.28	14.84
	6	704.68	162.70	12.56	845.15	0.0%	189.98	14.67
5	7	713.15	162.42	12.54	852.91	0.0%	189.64	14.64

Table 4.18b Weighted Average of Units Sold below Efficiency Levels, Electric Ovens, non Self-Cleaning

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	399.08	399.08	399.08	399.08	399.08
Annual Operating Cost (1990 $)					
Field	21.23	21.23	21.23	21.23	21.23
Proposed Test Proc.	25.16	25.16	25.16	25.16	25.16
Life-Cycle Cost at 6% (1990 $)	635.84	635.84	635.84	635.84	635.84
Energy Use (*kWh/yr*)	274.94	274.94	274.94	274.94	274.94

Table 4.18c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Electric Ovens, non Self-Cleaning

Efficiency Level	1	2	3	4	5
LCC Difference	6.1	9.0	-5.8	-88.2	-217.1
Payback (years)					
Field	3.8	6.2	13.8	22.0	36.2
Proposed Test Proc.	3.2	5.1	11.4	18.1	29.8
CCE *(cent/kWh)*	2.7	4.3	9.6	15.2	25.0

Table 4.19a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Electric Ovens, Self-Cleaning

Efficiency Level	Design No.	Installed Consumer Cost	Field Elec. Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Elec. Use	PTP Operating Cost
		(1990$)	*kWh/yr*	(1990$/yr)	(1990$)		*kWh/yr*	(1990$/yr)
1,2,3	0	630.16	303.72	23.45	891.63	100.0%	348.68	26.92
4	1	817.31	220.02	16.99	1006.53	0.0%	247.26	19.09
	2	854.96	215.54	16.64	1040.67	0.0%	241.84	18.67
	3	867.53	215.27	16.62	1053.44	0.0%	241.52	18.65
5	4	989.19	213.73	16.50	1173.11	0.0%	239.61	18.50

Table 4.19b Weighted Average of Units Sold below Efficiency Levels, Electric Ovens, Self-Cleaning

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	N/A	630.16	630.16
Annual Operating Cost (1990 $)					
Field	N/A	N/A	N/A	23.45	23.45
Proposed Test Proc.	N/A	N/A	N/A	26.92	26.92
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	N/A	891.63	891.63
Energy Use (*kWh/yr*)	N/A	N/A	N/A	303.72	303.72

Table 4.19c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Electric Ovens, Self-Cleaning

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	N/A	-114.9	-281.5
Payback (years)					
Field	N/A	N/A	N/A	29.0	51.7
Proposed Test Proc.	N/A	N/A	N/A	23.9	42.6
CCE *(cent/kWh)*	N/A	N/A	N/A	20.0	35.8

Table 4.20a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Gas Ovens, non Self-Cleaning

Efficiency Level	Design No.	Installed Consumer Cost	Field Gas Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Gas Use	PTP Operating Cost
		(1990$)	*MMBtu/yr*	(1990$/yr)	(1990$)		*MMBtu/yr*	(1990$/yr)
1,2	0	479.49	2.98	17.70	677.00	23.4%	3.58	21.27
3	1	525.30	1.52	11.01	648.18	76.6%	2.13	15.39
	2	534.91	1.45	10.60	653.15	0.0%	2.03	14.78
4	3	538.30	1.44	10.48	655.21	0.0%	2.01	14.67
	4	599.93	1.37	10.23	714.06	0.0%	1.91	14.31
	5	604.67	1.36	10.17	718.13	0.0%	1.90	14.26
5	6	674.00	1.36	10.17	787.46	0.0%	1.90	14.25

Table 4.20b Weighted Average of Units Sold below Efficiency Levels, Gas Ovens, non Self-Cleaning

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	479.49	514.59	514.59
Annual Operating Cost (1990 $)					
Field	N/A	N/A	17.70	12.58	12.58
Proposed Test Proc.	N/A	N/A	21.27	16.76	16.76
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	677.00	654.92	654.92
Energy Use (*MMBtu/yr*)	N/A	N/A	2.98	1.86	1.86

Table 4.20c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Gas Ovens, non Self-Cleaning

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	28.8	-0.3	-132.5
Payback (years)					
Field	N/A	N/A	6.8	11.3	66.2a
Proposed Test Proc.	N/A	N/A	7.8	11.3	63.4
CCE (*$/MMBtu*)	N/A	N/A	2.8	5.0	28.5

Table 4.21a Cost (1990$) and Energy-Use (Field Usage and Proposed Test Procedure) Summary of Gas Ovens, Self-Cleaning

Efficiency Level	Design No.	Installed Consumer Cost	Field Gas Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution	PTP Gas Use	PTP Operating Cost
		(1990$)	*MMBtu/yr*	(1990$/yr)	(1990$)		*MMBtu/yr*	(1990$/yr)
1,2,3,4	0	829.27	1.66	13.64	981.22	100.0%	2.16	17.38
	1	864.86	1.43	12.45	1005.91	0.0%	1.83	15.70
	2	878.73	1.42	12.39	1017.25	0.0%	1.82	15.65
	3	882.30	1.41	12.39	1020.25	0.0%	1.81	15.58
5	6	1032.87	1.36	12.03	1167.27	0.0%	1.73	15.12

Table 4.21b Weighted Average of Units Sold below Efficiency Levels, Gas Ovens, Self-Cleaning

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	N/A	N/A	829.27
Annual Operating Cost (1990 $)					
Field	N/A	N/A	N/A	N/A	13.64
Proposed Test Proc.	N/A	N/A	N/A	N/A	17.38
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	N/A	N/A	981.22
Energy Use (*MMBtu/yr*)	N/A	N/A	N/A	N/A	1.66

Table 4.21c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Gas Ovens, Self-Cleaning

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	N/A	N/A	-186.1
Payback (years)					
Field	N/A	N/A	N/A	N/A	126.6
Proposed Test Proc.	N/A	N/A	N/A	N/A	89.9
CCE (*$/MMBtu*)	N/A	N/A	N/A	N/A	60.8

Table 4.22a Cost (1990$) and Energy-Use (Field Usage) Summary of Microwave Ovens

Efficiency Level	Design No.	Installed Consumer Cost	Field Elec. Use	Field Operating Cost	Life-Cycle Cost	1999 Distribution
		(1990$)	*kWh/yr*	(1990$/yr)	(1990$)	
1,2,3,4	0	189.00	143.20	11.06	312.35	100.0%
	1	195.88	136.11	10.51	313.25	0.0%
	2	208.69	135.58	10.47	325.79	0.0%
	3	228.83	133.54	10.31	344.03	0.0%
5	4	254.50	132.43	10.22	369.08	0.0%

Table 4.22b Weighted Average of Units Sold below Efficiency Levels, Microwave Ovens

Efficiency Level	1	2	3	4	5
Installed Consumer Cost (1990 $)	N/A	N/A	N/A	N/A	189.00
Annual Operating Cost (1990 $)	N/A	N/A	N/A	N/A	11.06
Life-Cycle Cost at 6% (1990 $)	N/A	N/A	N/A	N/A	312.35
Energy Use (*kWh/yr*)	N/A	N/A	N/A	N/A	143.20

Table 4.22c Life-Cycle Cost Difference (1990$), Payback Periods (years) and Costs of Conserved Energy (@6%) of Microwave Ovens

Efficiency Level	1	2	3	4	5
LCC Difference	N/A	N/A	N/A	N/A	-56.7
Payback (years)	N/A	N/A	N/A	N/A	78.8
CCE *(cent/kWh)*	N/A	N/A	N/A	N/A	54.5

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Table 3.1 Energy Efficiency Levels for Cooktops, Ovens and Microwave Ovens

	Energy Efficiency Level				
	1	2	3	4	5
Engineering design option:					
Electric Cooktop, Coil Element	0	1	1	2	2
Electric Cooktop, Smooth Element	0	0	0	0	2
Gas Cooktop	0	0	1	1	3
Electric Oven, Non-Self-cleaning	1	2	3	4	7
Electric Oven, Self-Cleaning	0	0	0	1	4
Gas Oven, Non-Self-Cleaning	0	0	1	3	6
Gas Oven, Self-Cleaning	0	0	0	0	4
Microwave Oven	0	0	0	0	4
Maximum annual energy consumption :					
Electric Cooktop, Coil Element (kWh)	235	225	225	223	223
Electric Cooktop, Smooth Element (kWh)	233	233	233	233	206
Gas Cooktop (MMBtu)	3.37	3.37	1.32	1.32	1.26
Electric Oven, Non-Self-cleaning (kWh)	263	252	248	170	162
Electric Oven, Self-Cleaning (kWh)	304	304	304	220	214
Gas Oven, Non-Self-Cleaning (MMBtu)	2.98	2.98	1.52	1.44	1.36
Gas Oven, Self-Cleaning (MMBtu)	1.66	1.66	1.66	1.66	1.36
Microwave Oven (kWh)	143	143	143	143	132

3.2 ENERGY CONSUMPTION

Tables 3.2a to Table 3.2e show the past and projected average energy use of new cooktops, ovens, and microwave ovens. The weighted-average is obtained by taking the product of the UEC for each class times a class-specific weighting factor, and then summing over the classes. The weighting factors for electric cooktops, electric ovens, and gas ovens are:

Electric Cooktop, Coil Element	0.85
Electric Cooktop, Smooth Element	0.15
Electric Oven, Non-Self-Cleaning	0.44
Electric Oven, Self-Cleaning	0.56
Gas Oven, Non-Self-Cleaning	0.76
Gas Oven, Self-Cleaning	0.24

The UEC of average new cooktops, ovens, and microwave ovens is projected to remain the same for units bought from 1993 to 1999 in the absence of amended standards.

Table 3.2a Unit Energy Consumption for New Electric Cooktops (Weighted-Average kWh/year)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	234.5					
1993	234.5					
1996	234.5					
1999	234.5	234.5	226.4	226.4	224.5	220.4
2015	226.4	226.4	226.4	226.4	224.5	220.4
2030	226.4	226.4	226.4	226.4	224.5	220.4

Table 3.2b Unit Energy Consumption for New Gas Cooktops (Weighted-Average Million Btu/Year)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	3.06					
1993	1.49					
1996	1.49					
1999	1.49	1.49	1.49	1.32	1.32	1.26
2015	1.49	1.49	1.49	1.32	1.32	1.26
2030	1.49	1.49	1.49	1.32	1.32	1.26

Table 3.2c Unit Energy Consumption for New Electric Oven (Weighted-Average kWh/year)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	291.1					
1993	291.1					
1996	291.1					
1999	291.1	285.9	280.9	279.2	197.8	191.1
2015	291.1	285.9	280.9	279.2	197.8	191.1
2030	291.1	285.9	280.9	279.2	197.8	191.1

Table 3.2d Unit Energy Consumption for New Gas Oven (Weighted-Average Million Btu/Year)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	2.43					
1993	1.82					
1996	1.82					
1999	1.82	1.82	1.82	1.56	1.49	1.36
2015	1.82	1.82	1.82	1.56	1.49	1.36
2030	1.82	1.82	1.82	1.56	1.49	1.36

Table 3.2e Unit Energy Consumption for New Microwave Oven (kWh/Year)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	143.2					
1993	143.2					
1996	143.2					
1999	143.2	143.2	143.2	143.2	143.2	132.4
2015	143.2	143.2	143.2	143.2	143.2	132.4
2030	143.2	143.2	143.2	143.2	143.2	132.4

Tables 3.3a to 3.3c present projections of energy savings for cooktops. Tables 3.3d to 3.3f show the energy savings for ovens, and Table 3.3g shows savings for microwave ovens. Energy efficiency levels are projected to produce cumulative energy savings for cooktops from zero for efficiency level 1 to 0.54 Quads for efficiency level 5, during the period 1999-2030. For the same time period, cumulative energy savings for ovens range from 0.08 Quads for efficiency level 1 to 2.05 Quads for efficiency level 5. For microwave ovens, the cumulative energy savings during the period 1999-2030 range from zero for efficiency level 1 to 0.33 Quads for efficiency level 5.

Table 3.3a U.S. Energy Consumption for Electric Cooktops (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.12					
1993	0.15					
1996	0.15					
1999	0.16	0.16	0.16	0.16	0.16	0.16
2015	0.18	0.18	0.17	0.18	0.17	0.16
2030	0.20	0.20	0.20	0.20	0.19	0.18
1999-2030	5.66	5.66	5.60	5.61	5.56	5.21
Cumulative Savings:		0.00	0.05	0.05	0.10	0.45
Percent of Base:		0.0%	1.0%	0.8%	1.7%	7.9%

Table 3.3b U.S. Energy Consumption for Gas Cooktops (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.13					
1993	0.10					
1996	0.09					
1999	0.08	0.08	0.08	0.08	0.08	0.08
2015	0.07	0.07	0.07	0.07	0.07	0.07
2030	0.08	0.08	0.08	0.08	0.08	0.08
1999-2030	2.41	2.41	2.41	2.22	2.23	2.32
Cumulative Savings:		0.00	0.00	0.19	0.18	0.09
Percent of Base:		0.0%	0.0%	7.8%	7.4%	3.8%

Table 3.3c U.S. Energy Consumption for Electric + Gas Cooktops (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.24					
1993	0.25					
1996	0.24					
1999	0.24	0.24	0.24	0.24	0.24	0.24
2015	0.25	0.25	0.25	0.24	0.24	0.23
2030	0.28	0.28	0.28	0.27	0.27	0.26
1999-2030	8.07	8.07	8.01	7.83	7.79	7.53
Cumulative Savings:		0.00	0.05	0.24	0.28	0.54
Percent of Base:		0.0%	0.7%	2.9%	3.4%	6.7%

Table 3.3d U.S. Energy Consumption for Electric Ovens (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.15					
1993	0.18					
1996	0.18					
1999	0.19	0.19	0.19	0.19	0.19	0.19
2015	0.23	0.23	0.22	0.23	0.16	0.16
2030	0.26	0.26	0.25	0.25	0.18	0.18
1999-2030	7.26	7.18	7.10	7.15	5.58	5.59
Cumulative Savings:		0.08	0.17	0.11	1.68	1.68
Percent of Base:		1.1%	2.3%	1.5%	23.1%	23.1%

Table 3.3e U.S. Energy Consumption for Gas Ovens (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.09					
1993	0.09					
1996	0.08					
1999	0.08	0.08	0.08	0.08	0.08	0.08
2015	0.09	0.09	0.09	0.08	0.08	0.07
2030	0.1 0	0.10	0.10	0.09	0.09	0.08
1999-2030	2.81	2.81	2.82	2.50	2.67	2.44
Cumulative Savings:		0.00	-0.01	0.31	0.15	0.37
Percent of Base:		0.0%	-0.2%	11.0%	5.2%	13.2%

Table 3.3f U.S. Energy Consumption for Electric + Gas Ovens (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.24					
1993	0.26					
1996	0.27					
1999	0.28	0.28	0.27	0.27	0.27	0.27
2015	0.32	0.31	0.31	0.30	0.25	0.24
2030	0.36	0.36	0.35	0.34	0.27	0.26
1999-2030	10.08	10.00	9.92	9.66	8.25	8.03
Cumulative Savings:		0.08	0.16	0.42	1.83	2.05
Percent of Base:		0.8%	1.6%	4.2%	18.1%	20.4%

Table 3.3g U.S. Energy Consumption for Microwave Ovens (Quadrillion Btu, Primary)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	0.03					
1993	0.12					
1996	0.13					
1999	0.14	0.14	0.14	0.14	0.14	0.14
2015	0.17	0.17	0.17	0.17	0.17	0.16
2030	0.20	0.20	0.20	0.20	0.20	0.19
1999-2030	5.40	5.40	5.40	5.40	5.40	5.07
Cumulative Savings:		0.00	0.00	0.00	0.00	0.33
Percent of Base:		0.0%	0.0%	0.0%	0.0%	6.1%

3.3 ANNUAL INSTALLATIONS

As shown in Table 3.4a through 3.4c, installations[1] of cooking equipment are affected by energy efficiency levels. This result is a function of the change in operating expense, change in equipment price, and market share elasticities. The projection shows a change of between 7.1% decrease and 0.1% increase from base for the various efficiency levels for cumulative shipments of electric cooktops from 1999 to 2030. For gas cooktops the projections show a change of between 0.2% decrease and 10.9% increase. For electric ovens, the projections show a change of 11.0% decrease and no increase. For gas ovens, the projections show a change of no decrease and 14.6% increase. For microwave ovens, the projections show a change of 0.1% decrease and no increase.

[1] If there are no imports or exports, annual installations are equivalent to domestic shipments. Domestic shipments can be calculated as annual installations, less imports, plus exports.

Table 3.4a Cumulative Installations of Cooktops (Millions)

		Energy Efficiency Level				
1999-2030	Base	1	2	3	4	5
Electric	131.0	131.0	131.0	131.2	130.6	121.7
Gas	85.6	85.6	85.6	85.4	86.0	94.9
Total	216.6	216.6	216.6	216.6	216.6	216.6
Change from Base:						
Electric		0.00	-0.01	0.19	-0.36	-9.33
Gas		0.00	0.00	-0.19	0.36	9.31
Total		0.00	0.00	0.00	0.00	-0.02
Percent Change:						
Electric		0.0%	0.0%	0.1%	-0.3%	-7.1%
Gas		0.0%	0.0%	-0.2%	0.4%	10.9%
Total		0.0%	0.0%	0.0%	0.0%	0.0%

Table 3.4b Cumulative Installations of Ovens (Millions)

		Energy Efficiency Level				
1999-2030	Base	1	2	3	4	5
Electric	122.6	122.6	122.4	121.9	109.1	111.2
Gas	92.2	92.2	92.4	92.8	105.7	103.5
Total	214.8	214.8	214.8	214.8	214.7	214.7
Change from Base:						
Electric		-0.03	-0.22	-0.65	-13.54	-11.42
Gas		0.03	0.22	0.65	13.47	11.29
Total		0.00	0.00	0.00	-0.07	-0.13
Percent Change:						
Electric		0.0%	-0.2%	-0.5%	-11.0%	-9.3%
Gas		0.0%	0.2%	0.7%	14.6%	12.2%
Total		0.0%	0.0%	0.0%	0.0%	-0.1%

Table 3.4c Cumulative Installations of Microwave Ovens (Millions)

		Energy Efficiency Level				
1999-2030	Base	1	2	3	4	5
	362.7	362.7	362.7	362.7	362.7	362.2
Change from Base:		0.00	0.00	0.00	0.00	-0.48
Percent Change:		0.0%	0.0%	0.0%	0.0%	-0.1%

3.4 APPLIANCES PRICES

Projections of the purchase prices for new cooktops, ovens, and microwave ovens in 1990 dollars are shown in Tables 3.5a to 3.5e. The prices typically increase when energy efficiency levels come into effect.

Table 3.5a Average Purchase Price for New Electric Cooktop (1990 Dollars Per Unit)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	194					
1993	194					
1996	194					
1999	194	194	198	198	204	321
2015	198	198	198	198	204	321
2030	198	198	198	198	204	321

Table 3.5b Average Purchase Price for New Gas Cooktop (1990 Dollars Per Unit)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	225					
1993	258					
1996	258					
1999	258	258	258	262	262	313
2015	258	258	258	262	262	313
2030	258	258	258	262	262	313

Table 3.5c Average Purchase Price for New Electric Oven (1990 Dollars Per Unit)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	529					
1993	529					
1996	529					
1999	529	530	533	541	712	868
2015	529	530	533	541	712	868
2030	529	530	533	541	712	868

Table 3.5d Average Purchase Price for New Gas Oven (1990 Dollars Per Unit)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	568					
1993	587					
1996	587					
1999	587	587	587	594	604	756
2015	587	587	587	594	604	756
2030	587	587	587	594	604	756

Table 3.5e Average Purchase Price for New Microwave Oven (1990 Dollars Per Unit)

		Energy Efficiency Level				
Year	Base	1	2	3	4	5
1981	189					
1993	189					
1996	189					
1999	189	189	189	189	189	255
2015	189	189	189	189	189	255
2030	189	189	189	189	189	255

3.5 NET PRESENT VALUE

The net present value (NPV) of energy efficiency levels for any product is calculated by first determining the difference in present value of unit life-cycle costs between the base case and efficiency level case each year. That difference is then multiplied by the efficieny level case shipments for the year. The NPV for the period (1999-2030) is the sum over the years of the annual values. A positive NPV of efficiency level results when the new units in the efficiency level case have lower present value of life-cycle cost than do new units in the base case. Table 3.6a through 3.6c show the NPV to society of the energy efficiency levels.

Table 3.6a Net Present Value for Cooktops Purchased from 1999-2030
(Billion 1990$ Discounted at 4%)[2]

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.00	0.17	0.17	0.27	0.45
Gas	0.00	0.00	0.31	0.32	0.61
TOTAL BENEFIT (energy):	0.00	0.17	0.48	0.59	1.05
Equipment costs:					
Electric	0.00	0.09	0.09	0.39	5.99
Gas	0.00	0.00	0.12	0.12	2.03
TOTAL COST (equipment):	0.00	0.09	0.21	0.51	8.02
NPV = benefit - cost:					
Electric	0.00	0.08	0.08	-0.12	-5.54
Gas	0.00	0.00	0.20	0.20	-1.43
TOTAL across fuels:	0.00	0.08	0.27	0.07	-6.97
RATIO: benefit/cost:	N/A	1.89	2.33	1.15	0.13

Table 3.6b Net Present Value for Cooktops Purchased from 1999-2030
(Billion 1990$ Discounted at 7%)

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.00	0.10	0.10	0.14	0.22
Gas	0.00	0.00	0.14	0.14	0.27
TOTAL BENEFIT (energy):	0.00	0.10	0.23	0.28	0.49
Equipment costs:					
Electric	0.00	0.06	0.06	0.23	3.32
Gas	0.00	0.00	0.06	0.07	1.12
TOTAL COST (equipment):	0.00	0.06	0.13	0.29	4.43
NPV = benefit - cost:					
Electric	0.00	0.03	0.03	-0.09	-3.10
Gas	0.00	0.00	0.07	0.07	-0.85
TOTAL across fuels:	0.00	0.03	0.11	-0.01	-3.95
RATIO: benefit/cost:	N/A	1.57	1.85	0.95	0.11

[2] Normalized to energy efficiency level case shipments.

Table 3.6c Net Present Value for Cooktops Purchased from 1999-2030
(Billion 1990$ Discounted at 10%)

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.00	0.06	0.06	**0.08**	0.12
Gas	0.00	0.00	0.07	0.07	0.13
TOTAL BENEFIT (energy):	0.00	0.06	0.12	0.15	0.25
Equipment costs:					
Electric	0.00	0.04	0.04	0.14	1.97
Gas	0.00	0.00	0.04	0.04	0.66
TOTAL COST (equipment):	0.00	0.04	0.08	0.18	2.63
NPV = benefit - cost:					
Electric	0.00	0.01	0.01	-0.06	-1.86
Gas	0.00	0.00	0.03	0.03	-0.53
TOTAL across fuels:	0.00	0.01	0.04	-0.03	-2.39
RATIO: benefit/cost:	N/A	1.32	1.51	0.81	0.09

Table 3.6d Net Present Value for Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 4%)[3]

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.25	0.49	0.57	4.08	4.46
Gas	0.00	0.00	0.77	1.15	1.57
TOTAL BENEFIT (energy):	0.25	0.49	1.35	5.23	6.03
Equipment costs:					
Electric	0.07	0.23	0.61	7.91	14.92
Gas	0.00	0.00	0.26	0.71	6.90
TOTAL COST (equipment):	0.07	0.23	0.87	8.62	21.81
NPV = benefit - cost:					
Electric	0.18	0.26	-0.04	-3.83	-10.46
Gas	0.00	0.00	0.51	0.44	-5.33
TOTAL across fuels:	0.18	0.26	0.47	-3.40	-15.79
RATIO: benefit/cost:	3.37	2.11	1.54	0.61	0.28

[3]Normalized to energy efficiency level case shipments.

Table 3.6e Net Present Value for Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 7%)

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.11	0.22	0.26	1.83	2.00
Gas	0.00	0.00	0.34	0.51	0.70
TOTAL BENEFIT (energy):	0.11	0.22	0.60	2.34	2.70
Equipment costs:					
Electric	0.04	0.13	0.34	4.36	8.23
Gas	0.00	0.00	0.14	0.39	3.80
TOTAL COST (equipment):	0.04	0.13	0.48	4.76	12.03
NPV = benefit - cost:					
Electric	0.07	0.09	-0.08	-2.53	-6.23
Gas	0.00	0.00	0.20	0.12	-3.10
TOTAL across fuels:	0.07	0.09	0.12	-2.41	-9.33
RATIO: benefit/cost:	2.75	1.72	1.25	0.49	0.22

Table 3.6f Net Present Value for Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 10%)

	Energy Efficiency Level				
	1	2	3	4	5
Fuel costs savings:					
Electric	0.06	0.11	0.13	0.91	0.99
Gas	0.00	0.00	0.17	0.25	0.34
TOTAL BENEFIT (energy):	0.06	0.11	0.30	1.16	1.33
Equipment costs:					
Electric	0.02	0.08	0.20	2.59	4.88
Gas	0.00	0.00	0.09	0.23	2.25
TOTAL COST (equipment):	0.02	0.08	0.28	2.82	7.12
NPV = benefit - cost:					
Electric	0.03	0.03	-0.07	-1.68	-3.89
Gas	0.00	0.00	0.08	0.02	-1.90
TOTAL across fuels:	0.03	0.03	0.01	-1.66	-5.79
RATIO: benefit/cost:	2.32	1.44	1.04	0.41	0.19

Table 3.6g Net Present Value for Microwave Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 4%)

	Energy Efficiency Level				
	1	2	3	4	5
BENEFIT (energy)	N/A	N/A	N/A	N/A	0.95
COST (equipment)	N/A	N/A	N/A	N/A	9.34
NPV = benefit - cost:	N/A	N/A	N/A	N/A	-8.39
RATIO: benefit/cost:	N/A	N/A	N/A	N/A	0.10

Table 3.6h Net Present Value for Microwave Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 7%)

	Energy Efficiency Level				
	1	2	3	4	5
BENEFIT (energy)	N/A	N/A	N/A	N/A	0.47
COST (equipment)	N/A	N/A	N/A	N/A	5.14
NPV = benefit - cost:	N/A	N/A	N/A	N/A	-4.67
RATIO: benefit/cost:	N/A	N/A	N/A	N/A	0.09

Table 3.6i Net Present Value for Microwave Ovens Purchased from 1999-2030
(Billion 1990$ Discounted at 10%)

	Energy Efficiency Level				
	1	2	3	4	5
BENEFIT (energy)	N/A	N/A	N/A	N/A	0.25
COST (equipment)	N/A	N/A	N/A	N/A	3.04
NPV = benefit - cost:	N/A	N/A	N/A	N/A	-2.79
RATIO: benefit/cost:	N/A	N/A	N/A	N/A	0.08